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THESIS

SOFTWARE METRICS FOR POST DEPLOYMENT SOFTWARE SUPPORT SYSTEMS: A CASE ANALYSIS FOR THE CHEMICAL ACCOUNTABILITY MANAGEMENT INFORMATION NETWORK

by

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June 2001

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The Clinger-Cohen Act of 1996 requires performance measurement of information technology systems. Measuring the performance of program management for the Chemical Accountability Management Information Network (CAMIN) system requires a thoughtful selection of useful metrics. The CAMIN is a complex Management Information System in the post deployment software system (PDSS) phase of the system life cycle. This research uses three primary sources for candidate metrics for a PDSS like CAMIN: 1) typical software metrics from DoD and commercial applications, 2) typical fielded software system metrics from DoD and commercial applications, and 3) case analysis of metrics currently used by CAMIN and other DoD systems in the PDSS phase. Analysis of these candidate metrics creates a concise list of combined metrics that are applicable to fielded software systems. The current primary issues of CAMIN program management establish the basis for selection of appropriate program management metrics from the candidate list. These issues are examined in a process to answer the primary research question, " What are appropriate metrics and measures for management of the Chemical Accountability Management Information Network?"

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SOFTWARE METRICS FOR POST DEPLOYMENT SOFTWARE SUPPORT SYSTEMS: A CASE ANALYSIS FOR THE CHEMICAL ACCOUNTABILITY MANAGEMENT INFORMATION NETWORK

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ABSTRACT

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TABLE OF CONTENTS

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LIST OF FIGURES

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LIST OF TABLES

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LIST OF ACRONYMS, DEFINITIONS, AND ABBREVIATIONS

24-7	24 hours a day, seven days a week
ABCDF	Aberdeen Chemical Disposal Facility, Aberdeen, MD
ACMS	Automated Configuration Management System
ADP	Automated Data Processing
AIS	Automation Information System
AMC	Army Materiel Command
ANCA	Anniston Chemical Activity, Anniston, AL
ANCDF	Anniston Chemical Disposal Facility, Anniston, AL
ATR	Ammunition Transfer Record
BGCA	Blue Grass Chemical Activity, Lexington, KY
BGCDF	Blue Grass Chemical Destruction Facility, Lexington, KY
BMT	Business Management Team
CAMDS	Chemical Agent and Munitions Disposal System, Tooele, UT
CAMIN	Chemical Accountability Management Information Network
CCB	Configuration Control Board
CDs	Compact Disks
CoCoMo	Constructive Cost Model
COTS	Commercial Off the Shelf
CRU	Computer Resource Utilization
CTF	Chemical Transfer Facility
CTIC	Center for Treaty Implementation and Compliance
CW	Chemical Weapons
CWC	Chemical Weapons Convention, a Multilateral Treaty
CWT	Customer Wait Time
DCD	Deseret Chemical Depot, Tooele, UT
DCE	Distributed Computing Environment
DLL	Dynamically linked library
DMZ	Demilitarized Zone, a nickname for the area between two firewalls
DoD	Department of Defense

DPG	Dugway Proving Ground, Dugway, UT
DTRA	Defense Threat Reduction Agency (Formerly Defense Nuclear Agency)
ECA	Edgewood Chemical Activity, Aberdeen, MD
ECBC	Edgewood Chemical Biological Center, Aberdeen, MD
EDM	Engineering Data Management System
FP	Function Point
FY	Fiscal Year
GIS	Geographic Information System
GSA	Government Services Administration
GUI	Graphical User Interface
IFPUG	International Function Point User Group
ISO	International Standards Organization
IT	Information Technology
IV&V	Independent Verification and Validation
JACADS	Johnston Atoll Chemical Agent Disposal System
JI	Johnston Island
LAN	Local Area Network
MARB	Materiel Assessment Review Board
MC	Mission Capable
MOU	Memorandum of Agreement
MSC	Major Subordinate Command (Under Army Materiel Command)
NECD	Newport Chemical Depot, Newport, IN
NECDF	Newport Chemical Disposal Facility, Newport, IN
NICP	National Inventory Control Point
NIPRNET	Non-Classified Internet Protocol Router Network
O&M	Operation and Maintenance
OPCW	Organization for the Prohibition of Chemical Weapons

OSD	Office of the Secretary of Defense
PBA	Pine Bluff Arsenal, Pine Bluff, AR
PBCA	Pine Bluff Chemical Activity, Pine Bluff, AR
PBCDF	Pine Bluff Chemical Disposal Facility, Pine Bluff, AR
PCD	Pueblo Chemical Depot, Pueblo, CO
PCR	Problem/Change Request
PDM	Product Data Management
PDSS	Post Deployment Software Support
Pert	Project Evaluation and Review Technique
PKI	Personal Key Identifier
PM	Program Manager
PMO	Program Management Office
POM	Program Objective Memorandum
PUCDF	Pueblo Chemical Disposal Facility, Pueblo, CO
QA	Quality Assurance
QDR	Quality Deficiency Report
RDA	Research, Development, and Acquisition
SBCCOM	Soldier and Biological Chemical Command
SEE	Software Engineering Environment
SEI	Software Engineering Institute
SEMA	Software Engineering Measurement and Analysis
SEPR	Software Enhancement and Problem Report
SLOC	Source Lines of Code
SMT	Stockpile Management Team
SSL	Secure Socket Layer
SSSF	Single Small-Scale Facility
STSC	U.S. Air Force's Software Technology Support Center
SW-CMM	Software Capability Maturity Model
TAV	Total Asset Visibility
TCM	Toxic Chemical Munitions (TCM), the database that preceded CAMIN
TOCDF	Tooele Chemical Destruction Facility, Tooele, UT

UMCD	Umatilla Chemical Depot, Umatilla, OR
UMCDF	Umatilla Chemical Disposal Facility, Umatilla, OR
VDD	Version Description Document
WARS	Worldwide Ammunition Reporting System
Y2K	Year 2000

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I. INTRODUCTION

A. PURPOSE

This research identifies, evaluates, and selects the metrics for program management (PM) of the Chemical Accountability Management Information Network (CAMIN), an automated information system (AIS) that is in the Post Deployment Software Support (PDSS) phase.

This new look at the program management metrics used for AIS in the PDSS phase is required to ensure that the system measures are appropriate to the phase of the system. Metrics provide the Program Manager (PM) tools to assess the program quality, trends, and requirements. During the PDSS phase, most systems undergo iterative development-type activities to maintain life cycle functionality. Systems also require concurrent maintenance and operations activities to optimize daily system operation.

Published software metrics target assistance in managing activities specific to the software development phase. These metrics are applicable during the PDSS phase to support iterative maintenance upgrades, but the metrics used must also consider the issues of fielded systems. This research considers typical metrics used in management of software development, in combination with typical metrics that managers can use in the management of fielded standard systems. The research focuses specifically on metrics and measures for fielded software systems in consideration of their applicability toward the CAMIN.

B. BACKGROUND

This study investigates the management and metrics of the CAMIN system. The CAMIN system is a database for accountability of chemical weapons (CW), former CW production facilities (CWPF), and other data that merits preservation in support of CW treaties. The system maintains its inventory controls like those used in a banking system, requiring transactions that fully document change of status, description, movement, or destruction of buildings, weapons, or equipment. The system purpose is twofold: 1) to enable compliance with Army wholesale and retail accountability regulations, and 2) to provide tracking and reporting required under the CW Treaty for short-notice inspections, continuous presence during destruction, and annual reporting obligations. The CAMIN supports users from specific organizations that have a CW-related mission within the Department of Defense (DoD).

The CAMIN system management utilizes the typical program management metrics of all programs. The program measures key areas like budgeting, funding, expenditures, performance, and schedule. This study addresses these common metrics, and considers other metrics that may be applicable to CAMIN.

The field of AIS is constantly changing and expanding. The effective management of AIS requires the use of specialized management tools and techniques, relative to standard DoD systems. The primary differences in AIS relate to work force needs, costs, and turnover rates, scheduling and planning of creative breakthroughs, and the high frequency of external environment changes.

Most of the current literature on managing AIS focuses on the initial development and acquisition of systems. However, there is a dearth of information on supporting and maintaining fielded automation systems. Documentation within DoD and commercial organizations erroneously implies that the development effort "completes" the system.

Fielded software systems require an accelerated iterative development. A manager can adapt to use developmental software metrics and measures. However, little information exists within DoD or commercial documents regarding the other management metrics that would be applicable for fielded software systems.

The Year 2000 (Y2K) scare was indicative of the need for more vigilant management of fielded software systems. Managers found systems to be technologically backward, and months of effort were required to repair the flaws. A few systems required a prohibitively costly effort to repair, and managers had to replace the entire system. For example, developers are not available to correct programs written in programming languages that are no longer commonly used. When the language is not common, programmers necessary to update older systems are no longer available or cost-effective, and developers no longer support the system languages with updates.

As managers field more AIS, the experiences that are now collected are valuable in managing future programs. This thesis documents the valuable information on metrics that managers can apply to the CAMIN system and other similar fielded software systems.

C. RESEARCH QUESTIONS

1. Primary Research Question

What are appropriate metrics and measures for management of the Chemical Accountability Management Information Network?

2. Subsidiary Research Questions

What is the CAMIN System, and how does its management occur?

What are typical management metrics and measures for fielded systems, and how do managers perform management on fielded systems?

What are Management Information Systems? What are the applications for these systems?

What are typical management metrics and measures for Development of Management Information Systems, and how do managers perform management for Management Information Systems during development?

What are the relevant acquisition phases and activities for Management Information Systems? In what ways are they similar to and different from those corresponding to other types of systems?

What measures of effectiveness can help to assess Management Information Systems metrics and measures during PDSS?

How can the results of this research be generalized? What lessons can be learned from this analysis?

D. SCOPE OF THESIS, LIMITATIONS, AND ASSUMPTIONS

This thesis addresses metrics for management of the CAMIN in the PDSS phase. It investigates lessons learned by managers of the CAMIN and of other similar systems. The thesis includes only systems in the PDSS phase that are managed within DoD.

The metrics identified and evaluated in this thesis are within the criteria of those specifically associated with software programs and those associated with fielded systems. The common metrics literature for software systems are oriented toward development, and do not address measures that would specifically apply to software systems in use.

This thesis defines the term "metrics" as a standard of measurement and the application of statistics and mathematical analysis to a specified field of study. The metrics described and defined in this thesis are specific ways of measuring and evaluating the defined aspects of the CAMIN program.

E. METHODOLOGY

This thesis methodology employs the case method. The case method includes three major elements of research. First, the thesis examines system management for the CAMIN system. Next, the thesis presents the results of a document search of common metrics that may be applicable to CAMIN. Finally, the thesis includes a study of metrics for similar systems. This research develops and analyzes data for applicability to the CAMIN Program.

The thesis documents the analysis of these data and makes specific recommendations for the CAMIN program management metrics. The data are a compilation of common documented metrics for software development and program

management, together with management metrics for other fielded software systems. This analysis assesses metrics for applicability based on past, current, and anticipated CAMIN management issues.

F. THESIS ORGANIZATION

The first chapter of this thesis provides a general introduction of the purpose, background, objectives, the research questions that apply to this study, scope, methodology, and expected benefits of the research.

Chapter II provides the background material to begin the research and analysis of this thesis. Following the introductory section is a detailed descriptive history of the CAMIN system, its missions, and functions, and how the organizational structure is set up to operate and manage the system. There is a discussion of the CAMIN system and its status with regard to the acquisition process. This chapter includes significant historic events and associated CAMIN program metrics. Finally, Chapter II defines and discusses the CAMIN program from the program management perspective concerning five basic issue areas.

In Chapter III, the thesis discusses the types of metrics that managers typically use in Management Information Systems. The chapter presents a detailed description of software system metrics identified through literature search. The types of metrics that managers typically use in program management of Fielded Systems are included. This chapter also addresses two fielded software systems that may be comparable to CAMIN. This chapter presents metrics identified through case study interviews of other fielded software systems. These data provide metrics and other data for analysis.

Chapter IV analyzes the data presented in the thesis. Chapter IV discusses observations from literature and other fielded software systems in reference to the CAMIN program areas of concern that may warrant metrics and measures. The observations create the basis for the final set of metrics for CAMIN. Data from the thesis data collection and analysis process generate lessons learned that are applicable to the subject.

Chapter V provides conclusions and recommendations. In addition to the conclusions that one can draw from the results and analysis, specific recommendations to the CAMIN program and recommendations to other fielded software systems Managers are included. The final output of the study is a listing and description of future research topics.

G. EXPECTED BENEFITS OF THIS THESIS

The results of this study provide direct benefit to the CAMIN Program. The PM selected the metrics historically used on the program, but with thoughtful evaluation, the system metrics that this thesis selects can have a direct and meaningful effect on the program's cost, schedule, and performance. Actively evaluating and selecting program metrics can help to guide future planning on the CAMIN system. The thesis should support future annual planning and management for the CAMIN System.

Finally, managers can use these results in planning for the PDSS phase of future automation systems. This study results in useful information that automation system managers may find applicable in planning and establishing metrics and measures for other fielded software systems.

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II. THE CAMIN SYSTEM, PAST AND PRESENT

The CAMIN system program management is complex due to the system size and number of applications, and management of complex systems warrants measures. The program has a history of collecting and interpreting metrics. This chapter provides a descriptive history of the CAMIN system and the historic approach to program metrics. Understanding the history of the program is important to accomplishing the objective of this thesis. Every program is unique, and requires individual analysis to determine appropriate metrics for the program in a given phase of development.

This chapter describes the CAMIN system, and its status with regard to the Acquisition Process. The CAMIN Program history has been very complex and unique, and this chapter includes a brief discussion of how CAMIN evolved through each of the acquisitions phases.

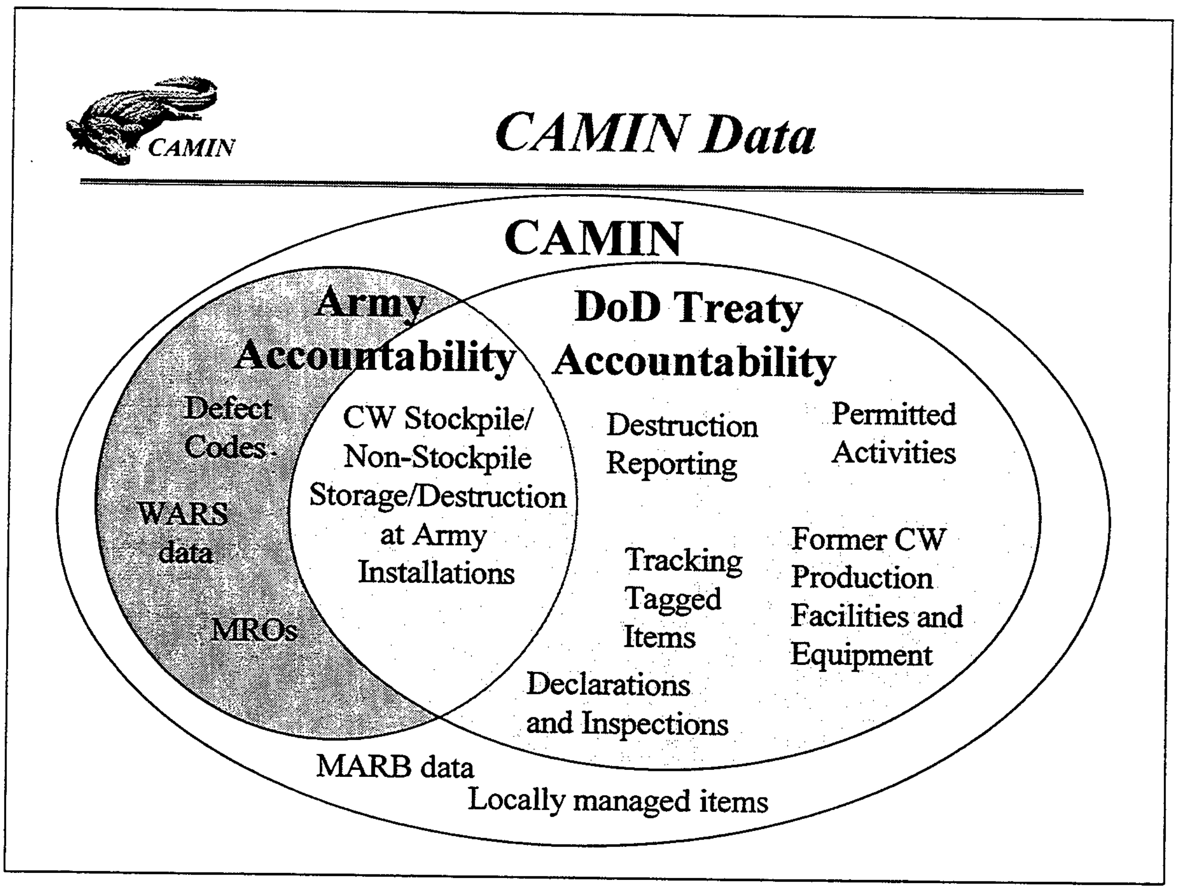
This chapter concludes with a listing of the key program management issues for CAMIN, and a breakdown of factors that contribute to these issues.

A. HISTORY OF CAMIN AND METRICS

1. CAMIN Mission

The CAMIN Program has been in existence for over six years. The CAMIN is a dual-purpose system, serving the chemical treaties for the DoD and the accountability mission for the Army's CW stockpile under the DoD Single Manager for Conventional Ammunition.

Key areas derived from these two missions drive the CAMIN configuration and architecture. The Treaty mission must support short-notice Treaty inspections. Because of the sensitive nature of the Treaty data and the potential for impact on international relations, there is a zero-tolerance goal in the CAMIN for data errors relative to Treaty reporting and accountability of chemical materiel. There are CAMIN users at sites throughout DoD, and these users need to access real-time data 24 hours a day, seven days a week (24-7). System administration controls permissions to ensure that only users with training and responsibility can change the data. The CAMIN must provide the ability to audit all data changes, and adequate security can help to protect the data in CAMIN.



[From Ref.15]

Figure 1. CAMIN Mission Data

Figure 1 shows the types of data tracked in CAMIN, and how those data fit into the major mission areas of CAMIN. As shown here, data exist in CAMIN that do not fall into either area, such as data for locally owned stocks. Users choose to store and maintain these data in CAMIN for convenience. Additionally, this thesis uses the terms "destruction" and "demilitarization" interchangeably, in conjunction with elimination of CW assets.

CAMIN provides tracking, accountability, and reporting required for DoD compliance with the Chemical Weapons Convention (CWC), [Ref 18] a Treaty formally known as the "Convention on the Prohibition of the Development, Production, Stockpiling, and Use of Chemical Weapons and on Their Destruction." The CWC is a multilateral Treaty, governed from The Hague, by the Organization for the Prohibition of Chemical Weapons (OPCW). As of 12 February 2001, 174 State Parties have signed the CWC, and 143 countries have ratified the treaty, including the United States [Ref. 19]. The CWC specifically addresses the destruction of CW and CWPF.

The CAMIN performs all of the user requirements using a familiar, windows-based interface. Screen captures for typical representative CAMIN applications are available for viewing in Appendix E.

CAMIN tracks locations of Treaty-declarable items within DoD at the geographical site, the declared area within the site, the building, and the grid within the building. The system tracks item information for the CWC such as nomenclature, serial number, and tags applied by inspectors. Documentation and information about historical

movements, destruction, or changes in item status reside in CAMIN. CAMIN maintains site diagrams for all declared facilities, as well as process flow diagrams of CWPF. CAMIN provides specially formatted reports for the short-notice Treaty inspections, while data from the system provides input to the annual reports submitted by the United States to the OPCW.

CAMIN also tracks Schedule 1 chemical material that the DoD maintains for permitted purposes under the CWC [Ref 18]. The CWC monitors and controls three schedules of chemicals. The Schedule 1 list mainly comprises the weapons-grade toxic chemicals. Schedule 2 and 3 chemicals include precursors to toxic chemicals, which are toxic chemicals that are commonly used for industrial purposes. The CAMIN system does not currently track information related to Schedule 2 or 3 chemicals, as DoD does not have Schedule 2 or 3 chemical assets that are subject to CWC monitoring. The CWC permits State Parties to develop, produce, otherwise acquire, retain, transfer, and use toxic chemicals and their precursors for purposes not prohibited under the convention. These permitted purposes are industrial, agricultural, research, medical, pharmaceutical, or other peaceful purposes. In support of short-notice inspections, the CAMIN tracks items that the DoD retains for these purposes as individual items. CAMIN also maintains the chemical amounts for Schedule 1 permitted activities to ensure that the DoD remains in compliance with Treaty thresholds for maximum storage and production levels.

In support of the CWC, CAMIN maintains auditable accountability records for CWPF equipment and for Schedule 1 permitted items. For CW, CAMIN also maintains

auditable accountability, not only for the CWC, but also in support of the Army's accountability mission.

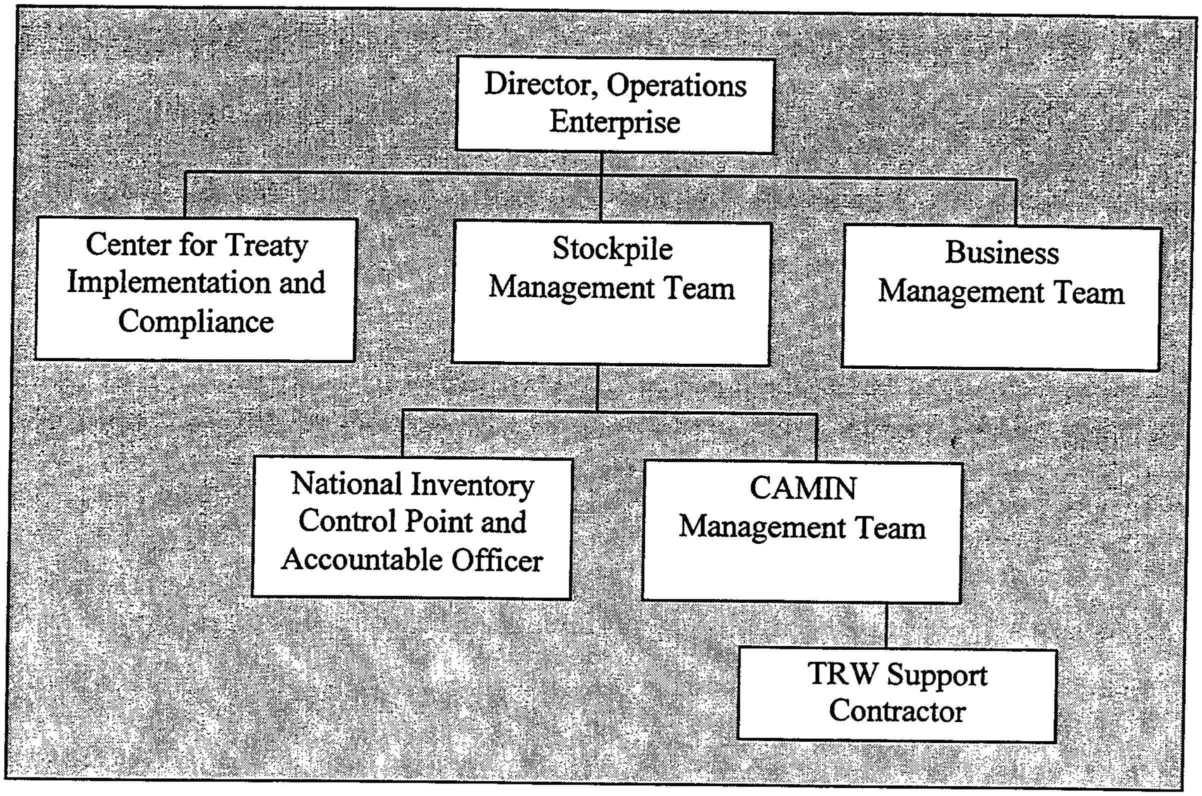
CAMIN maintains strict accountability of all wholesale CW, chemical-peculiar equipment, and bulk storage of chemical materiel. CAMIN ensures compliance with U.S. Army and Army Materiel Command regulations that govern wholesale property accountability. CAMIN gives a full audit trail for change to status, nomenclature, codes, location, or destruction. CAMIN provides documents and application for performing annual inventories of the chemical materiel. Data in CAMIN include building lists, site diagrams, and movement and destruction records. CAMIN provides diagrams of the buildings and the specific grid locations that store items. The weapons and production equipment information in CAMIN includes not only location, but also description, serial numbers, Army codes for condition and ownership, and other parameters.

In addition to its two primary designed purposes, CAMIN also permits system users to track locally owned stocks, defect codes, and other codes for munitions that are not required for CWC or Army wholesale accountability.

2. CAMIN Management and Funding Structure

The Defense Threat Reduction Agency developed the CAMIN system, and then transitioned program ownership to the U.S. Army Soldier and Biological Chemical Command in 1997. Presently, CAMIN program management resides within the Operations Enterprise of the Soldier and Biological Chemical Command (SBCCOM). The Stockpile Management Team performs functions required to manage the CAMIN

program, but the funding and approval process involves multiple organizations within the enterprise, as shown in Figure 2.



[Developed by Researcher]

Figure 2. CAMIN Management Organization

The two primary sources of funding for the CAMIN program are storage and treaty. There is a negotiated agreement for the distribution of funding requirements, between storage and treaty, for the Operation and Maintenance (O&M) Phase of the program. Before transition of Army wholesale accountability to CAMIN, the Treaty program funded the entire system. After transition, the "customer" who requires the system upgrade is responsible for funding the upgrade. In essence, the customer funds

the effort to accomplish its specific requirement. For activities of general benefit, such as user support and system administration, a basic allocation shown in Table 1 uses the number of active CW storage sites as a parameter to determine funding allocations. The Treaty portion of the funding for these general costs increases as CW Stockpile sites complete destruction activities. In this table, the term "CW Sites" refers to the number of active CW Stockpile Storage Sites during that fiscal year (FY). The number compares to the baseline total number of nine stockpile sites, to calculate the portion of funding for Treaty vs. storage. For example, Johnston Atoll Chemical Agent Disposal System (JACADS) completed destruction in FY 01, and in FY 02, there is one less CW site to support. These numbers, based on current destruction schedules, are subject to revision. Understanding this funding and management structure helps to understand the metrics that this program must collect. Only by defining appropriate metrics can the program justify adequate funding to maintain system operations.

	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08 and Future
CW Sites	9/9	8/9	8/9	7/9	7/9	4/9	4/9	0/9
Treaty	60%	64%	64%	68%	68%	80%	80%	100%
Storage	40%	36%	36%	32%	32%	20%	20%	0%

[From Ref. 14]

Table 1. CAMIN Funding Allocation

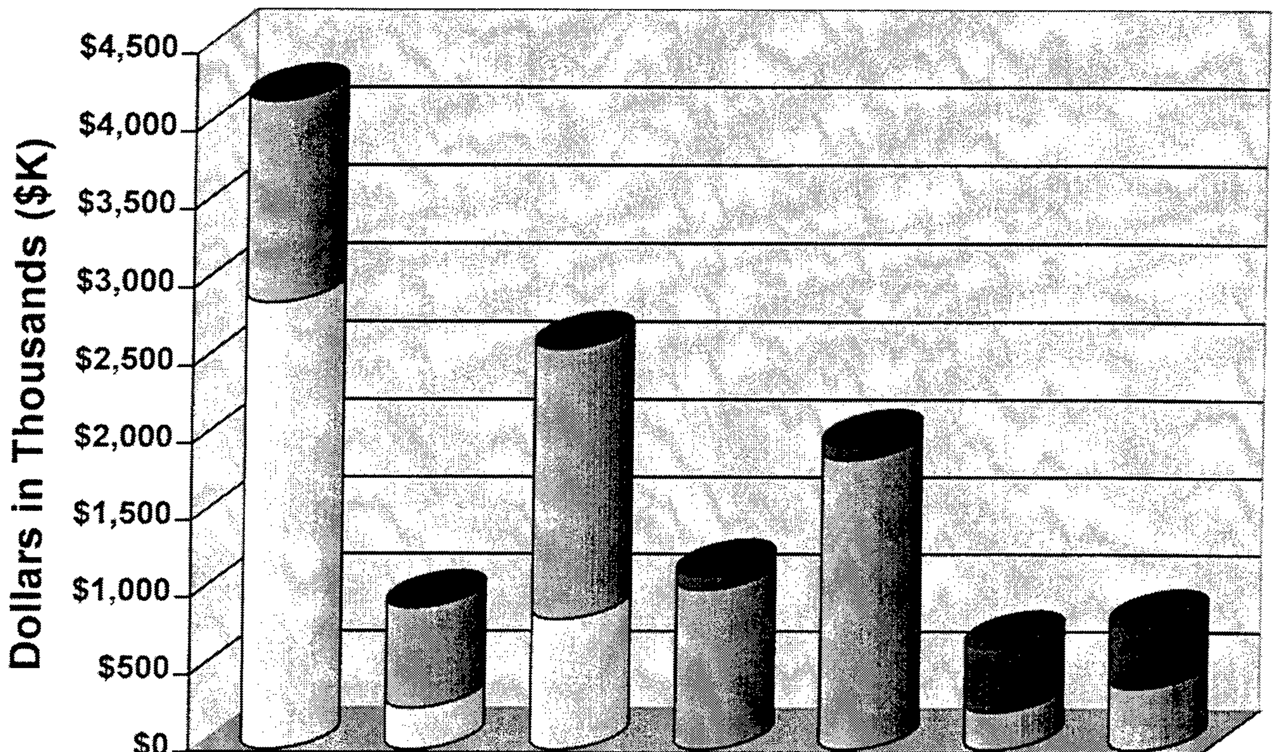
personally involved with the issuance of storage funding. Within the Operations enterprise, three organizations are involved in CAMIN management and funding: 1) The Stockpile Management Team, 2) the Center for Treaty Implementation and Compliance (CTIC), and 3) the Business Management Team (BMT).

The Stockpile Management Team (SMT) provides the overall CAMIN management and serves as the National Inventory Control Point and Accountable Officer for CW and Chemical-Unique Containers. The team leader participates in the budgeting process for storage funding.

A team acting as a program management office (PMO) performs CAMIN management functions within the SMT. The PMO for CAMIN performs business planning and budgeting for the CAMIN program. The majority of funding for CAMIN goes into the support contract, for user support and training, system administration, data administration, hardware and software purchase, software maintenance and support. In addition to business planning, budgeting, planning, and execution, CAMIN program management functions performed by Government personnel include help desk configuration management, data management, and data administration. The program areas that follow provide detailed descriptions of these tasks.

As stated above, the National Inventory Control Point (NICP) and Accountable Officer missions for CW and Chemical-Unique Containers missions reside within the Stockpile Management Team. In addition to its role as an active user of CAMIN, the NICP/Accountable Officer also provides policy guidance for the CAMIN program in the areas of storage and accountability. Additionally, when the CAMIN program needs

funding to satisfy a new or modified requirement, this organization provides storage funding approval to the decision makers for storage funding within the Operations Enterprise.



	93-95	1996	1997	1998	1999	2000	2001
Storage	$0	$0	$0	$90	$87	$415	$400
Treaty	$1,289	$650	$1,751	$1,031	$1,876	$245	$400
R&D	$2,884	$265	$839	$0	$0	$0	$0

Fiscal Year

[After Ref. 14]

Figure 3. CAMIN Funding History

The CTIC performs Treaty Management for SBCCOM and for the CAMIN program. They provide Treaty Policy Support and Treaty Funding. They also act as Configuration Control Board (CCB) Co-Chair. When the CAMIN program needs funding to satisfy a new or modified requirement, this organization provides approval for Treaty funding, as well as the funding.

The BMT within the Operations Enterprise manages all funding that comes into the enterprise. The BMT distributes all funding that the CTIC later allocates to the CAMIN Program. The BMT manages the storage funding, and only issues this funding to the CAMIN program with authorization from the Operations Enterprise Director and the NICP.

The chart of CAMIN Funding History [Figure 3] shows the funding levels and sources. The CAMIN program has never successfully conformed to the funding allocation profile that comprised the agreement between storage and Treaty in FY 99. As a result, managing funding for the CAMIN program requires intense coordination every year. The PMO must determine how much funding is required, request funding based on allocation agreement, and renegotiate based on actual funding allocated from the funding sources.

3. CAMIN System Description

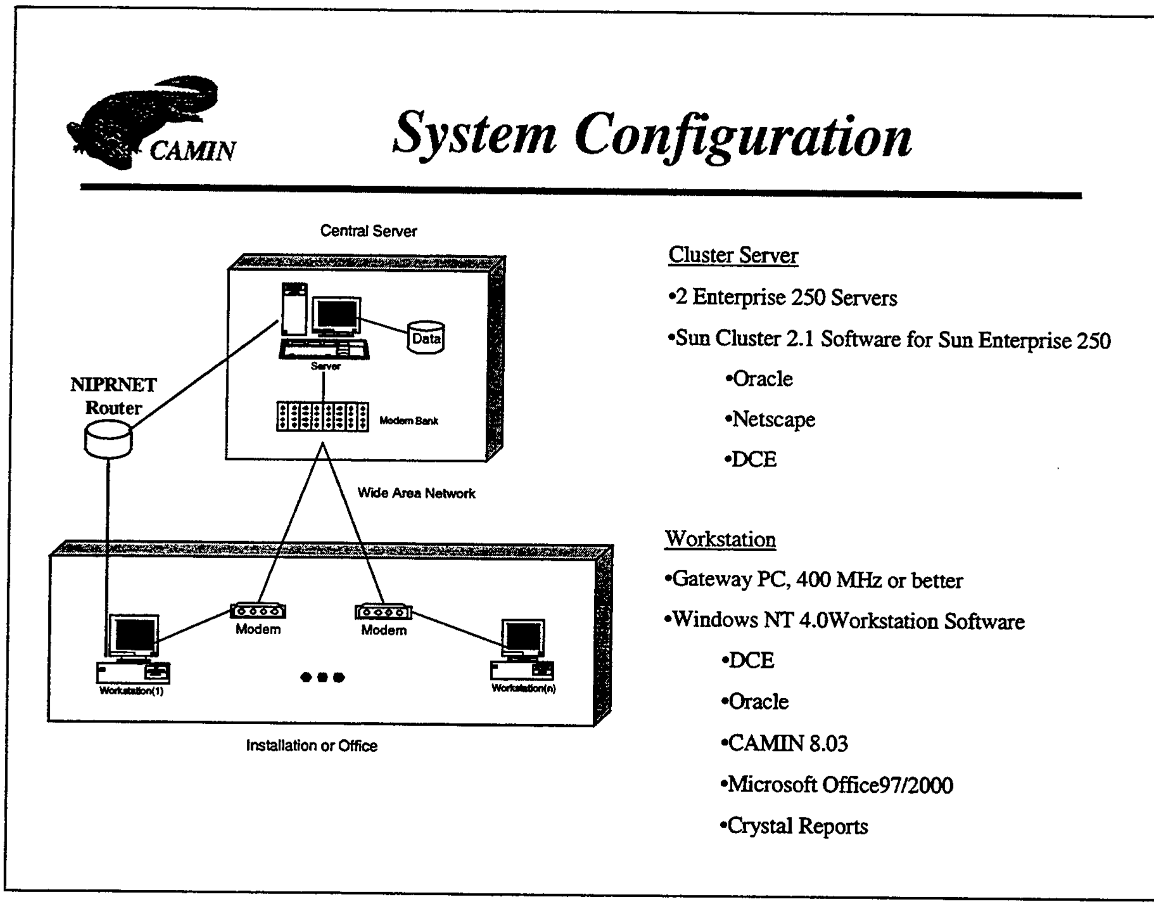
The CAMIN program is a stand-alone system, designed to maintain mission data and allow data retrieval by all authorized users on a 24-7 real-time basis. CAMIN management strictly controls user access permissions to ensure that data remain as accurate as possible.

CAMIN is a client-server system, where the CAMIN server is centrally located with CAMIN server software, and users operate the system on client software installed on remote workstations. The CAMIN Server is located at SBCCOM, Aberdeen, MD. Workstations are located at Army and contractor sites in the continental United States and the Pacific. The client platforms for CAMIN use Microsoft Windows™ to provide a familiar interface for the user community. The CAMIN server operates as a Web server to allow users, which have proper permission, to access a limited set of CAMIN functionality through a web browser interface.

The CAMIN Architecture design depicted in Figure 4 provides access to data while maintaining security of the system and data. The primary areas that can contribute to the system vulnerability are the server, connectivity, and workstation. CAMIN has a published Continuity of Operations Plan that addresses these issues.

The CAMIN Server is a highly available cluster design, with two mirrored servers, and the identical data set resides in both units. If the active server unit goes down, the system automatically switches over to the other server unit in the cluster and continues operation. Power outages at the server location are a source of concern, and the server hardware suite includes uninterruptible power supplies to smoothly shut down the server in case of power outage. The building in which the server resides is vulnerable to power outages and air conditioner failures. One preventative measure against future outages is air conditioner system replacement. The system administrators back up CAMIN data to a remote location daily and the system administrator can access backup data from the remote location if there is a systemic power failure at SBCCOM.

Precautions can be justified though experience. The server cluster experienced a systemic and long-term power failure at the server location, caused by hurricane Floyd in September 1999, while one of the client sites was trying to prepare for a short-notice Treaty inspection. The system administrator used data backups to meet the immediate need, but plans are now in place to help mitigate future problems.



[After Ref. 14]

Figure 4. CAMIN System Architecture

Connectivity is another area of vulnerability. Consequently, there are multiple ways to provide access between CAMIN server and workstation, to include both Local

Area Network (LAN) and phone for the workstation client software, and web access. The other issue of connectivity involves the implementation of firewalls for security. Firewalls at server and client locations can block user access to the CAMIN server. Firewalls can block partial or total connection, depending on firewall settings. The CAMIN manager periodically monitors firewall settings and advises local Corporate Information Offices (CIOs) at firewall sites to ensure that CAMIN data and other required information can pass through the firewall. The CAMIN server is located on the network within an area of the SBCCOM firewall known as the DMZ, a "demilitarized zone" that is not completely within the firewall, but within a protected area at the firewall interface. This location permits users to access the system while retaining well-defined security benefits.

The workstation and client software can also contribute to CAMIN vulnerability. The CAMIN workstations must have a special configuration to operate CAMIN client software, including a specific and atypical operating system, Windows NT 4.0. The installation of client software must be correct to allow CAMIN functionality. Other pieces of software or hardware installed on the workstation can interfere with CAMIN functionality. Users must gain approval from the CAMIN management team before installing new software or hardware onto their CAMIN workstation. For example, one CAMIN user loaded an unauthorized screen saver onto her workstation, and the screen saver increased the default font on her workstation so that CAMIN data did not appear in the text boxes on her workstation. This change was very difficult to diagnose and detect.

CAMIN authorized users can also access CAMIN data through the recently introduced web site. Users now have web access to frequently used CAMIN data reports. An expansion of web capability is planned that allows users to perform all workstation functionality through a web browser-based interface. This action resolves all workstation configuration, cost, and maintenance issues by eliminating the need for stringent workstation requirements. The web design distills the firewall connectivity issues to configuration of one common web port.

4. CAMIN Program Areas

CAMIN program management includes short and long-term program budgeting, business and strategic planning, and organizational and contractual activities. Program management also includes oversight of the areas of user support, O&M, and requirements upgrades for the CAMIN system. The CAMIN Management Team within the Stockpile Management Team is responsible for all areas listed in Table 2.

a. Overarching Management

CAMIN overarching management includes budgeting and execution, planning, reporting, and concept design, data management, contract management, configuration management, and hardware and software acquisition. The budgeting and execution process explanation is contained in the previous section.

Overarching	User Support	Administration	Upgrades
Budgeting and Execution	Help Line	System Administration and Security	Design and Development
Planning, Reporting, and Concept Design	Training	Data Administration	Code Writing
Data Management	User Manual	Network and Firewall	Testing
Contracting and Contract Management	User Group Meetings	Web Administration	Fielding
Configuration Management	Newsletters and Announcements	Workstation Administration	
Hardware and Software Acquisition			

[Developed by Researcher]

Table 2. CAMIN Program Management Areas

Planning, reporting, and concept design encompasses a large scope of activities. Generating strategic and business plans requires a study and application of trends in information technology, and development and application of metrics. The PMO passes on important information to Treaty and accountability management and through the organizational hierarchy to the DoD level. Policies for the CAMIN program establish consistency across users, workstations, and within SBCCOM, Army Materiel Command (AMC), and Army.

Data management includes all work toward improving the accuracy of data in CAMIN. The NICP, system users, and CTIC are involved in the process to identify and analyze data errors. Users or data administration accomplish data corrections. Defining the cause of the errors leads to corrective actions, including new problem/change requests (PCRs), enhanced training, and enhanced user manuals. PCRs document requests for changes to the CAMIN software or system. Users of CAMIN software or data generate the PCRs that the CCB evaluates for disposition. Data management and administration activities are important, expensive, and time consuming to CAMIN Program Management. Challenges to the CAMIN data come through user error, data migration from one version to the next, and through policy changes. CAMIN maintains a strict audit trail of data changes, including documentation of the user that caused the change. Additionally, CAMIN uses quality assurance (QA) by requiring a second user login to "QA" the data change before making the actual data change in the system. Annual inventories and Treaty inspections further validate the data. User error requires frequent audits. However, proactive measures are used to find these errors before the external community becomes aware of them. However, data migration errors are difficult to identify before they occur. Policy changes often affect data, and the associated problems are targeted through analysis and testing.

The contract management area ties closely to budgeting, funding execution, planning, and upgrades. The CAMIN contract is comprised of seven phases. Phase 1 is User Support, Phase 2 is System Maintenance, Phase 3 is Server Maintenance, Phase 4 is Meetings, Phase 5 is Special Studies, Phase 6 is Hardware and Software

Acquisition, Configuration, and Fielding, and Phase 7 is System Version Upgrades. Funding sources provide incremental funding, and this makes planning difficult. The PM gives the contractor guidelines to establish which tasks to devote their time, and how to establish a workforce. Retention of Information Technology (IT) workers in the current hiring environment requires consistent funding and interesting and consistent work.

Configuration management controls software, hardware, data, and documentation for the system. The configuration management plan defines roles and responsibilities. The system configuration manager is the PM. There are two co-chairs of the CCB, representing Treaty and accountability/storage as the two missions of CAMIN. The CCB reviews PCRs from data and system users, and has the authority to approve system changes. The CCB consists of representatives from funding, users, and other primary CAMIN customers. The CCB makes decisions based on sound business criteria. Criteria for analysis include the need and benefit of a change, the risks, the potential funding availability, the costs, and the difficulty/time required to introduce the change.

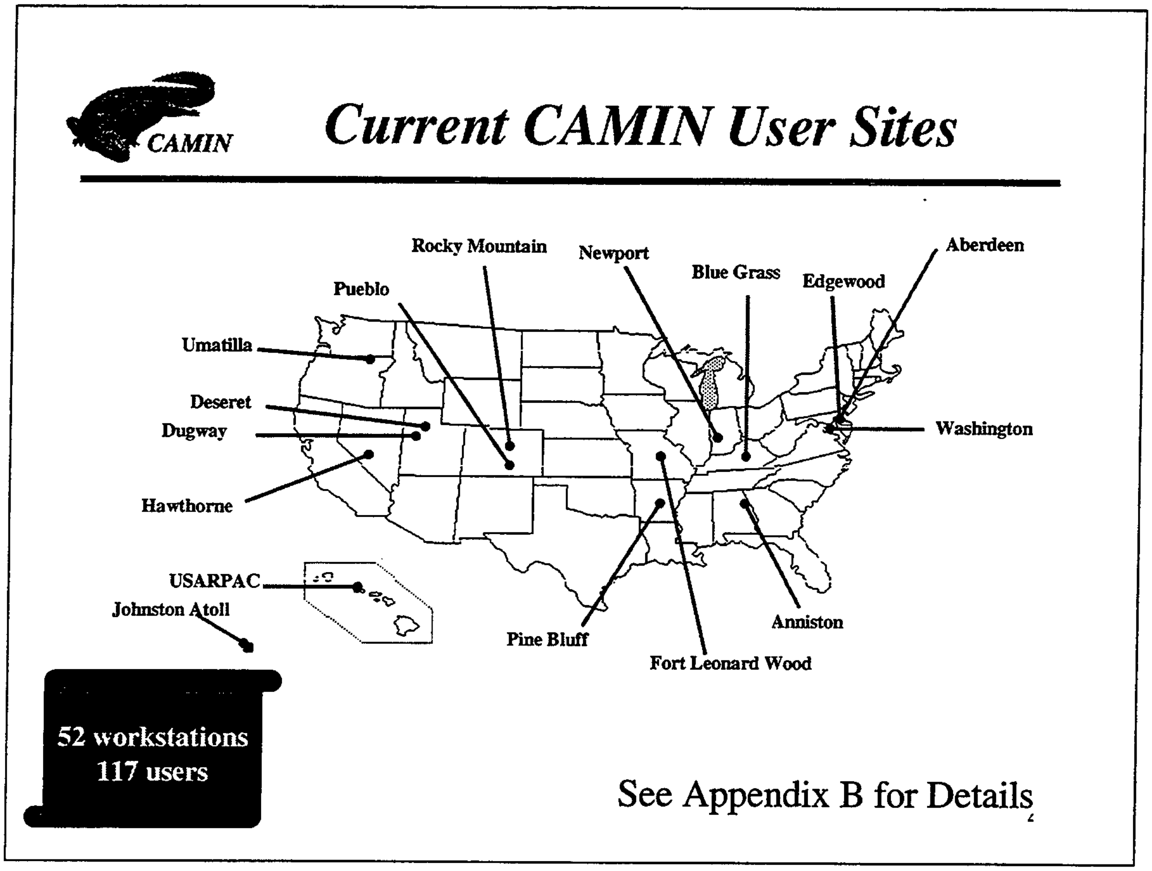
Hardware and Software Acquisition requires forward planning. The workstation acquisitions tie to the three-year maintenance agreements and to the fluctuating workload associated with the destruction effort. Active destruction at each major facility increases the workload (and workstation) requirements by about five. The acquisition of workstation hardware and software ties to the support contract. The contractor configures the workstations, loading software and ensuring functionality through phone and LAN connection before delivery. Figure 5 shows the location of

connection before delivery. Figure 5 shows the location of CAMIN users. Appendix B provides a detailed listing of current CAMIN users and locations.

b. User support

User support covers help line, training, user group meetings, web notices, and announcements. User competence is an area that is critical to the CAMIN system, to help ensure that CAMIN data is correct and timely. The user group is geographically diverse; users are located all across the country [Figure 5]. The education and experience level of users vary from SES and full Army Colonels to GS-05 clerks that have only used a computer for CAMIN. Help line support is available during working hours, and a 24-hour emergency pager is available to support after-hour emergencies. Scheduled training classes are offered both on-line and in a classroom-style training environment.

Each version of the software includes all relevant documentation, including a full user manual loaded onto the CAMIN desktop. An on-line training database within the CAMIN system allows users to practice an activity and evaluate results against expectations. Users can switch to the training database to test or practice a process before affecting the live database. An additional training tool offered is the computer-based training CDs. Annual Data Management User Group meetings invite all users to participate in meetings to discuss the current and future activities of the CAMIN Program. Breakout sessions with user subgroups provide an additional venue for contact and feedback with users. Finally, local administrators at workstation locations manage the workstation configuration, including permissions and access for users, and settings for the local networks and firewalls to permit CAMIN access.



[After Ref.14]

Figure 5. CAMIN Workstation Sites and Users

c. Administration

Operation of the CAMIN system includes system administration and security activities, data administration, network and firewall, web administration, and workstation administration. System administration manages and maintains server operations on a daily basis, managing file sizes and system operations. The system administrator issues and maintains user accounts, passwords, and permissions. Security is of primary concern. Although data in CAMIN is not classified, much of it is For

Official Use Only. Passwords and permissions control system access. CAMIN uses a commercial off-the-shelf (COTS) middleware software package called Distributed Computing Environment (DCE) on the workstations to provide access controls for client security. The client connections pass over the NIPRNET, an Army version of the Internet. For the web, Personal Key Identifier (PKI) and Secure Socket Layer (SSL) maintain a secure connection and encrypt data passing over the web.

Data administration in CAMIN is required for correcting data errors, making top-level changes to data, and for collecting metrics about data in the CAMIN system. The CAMIN architecture is set up so that system users have no direct access to the CAMIN database. The CAMIN system is extremely complex, with over 800,000 lines of software code, and 3.8 Gigabytes of data files. Table 3 summarizes CAMIN lines of code, and Appendix C contains information that is more detailed. Direct access to the CAMIN database to change system data is limited to three people. The data administrators use a strict control process to monitor and approve data changes.

As stated in the previous section, network and firewall issues can contribute to the vulnerability of the CAMIN system. Coordination with local administrators helps to ensure that network and firewall configurations are compatible with CAMIN. The CAMIN web site resides on the CAMIN server cluster. Web site administrators maintain links, post announcements, maintain the calendar, and ensure connectivity.

CAMIN Code Area	Count of Lines of Code
NT Applications	372,603
Server Applications	344,462
Web Applications	77,173
Report Templates	27,000
Database Structure	10,281
System Totals	831,519

[After Ref. 4]

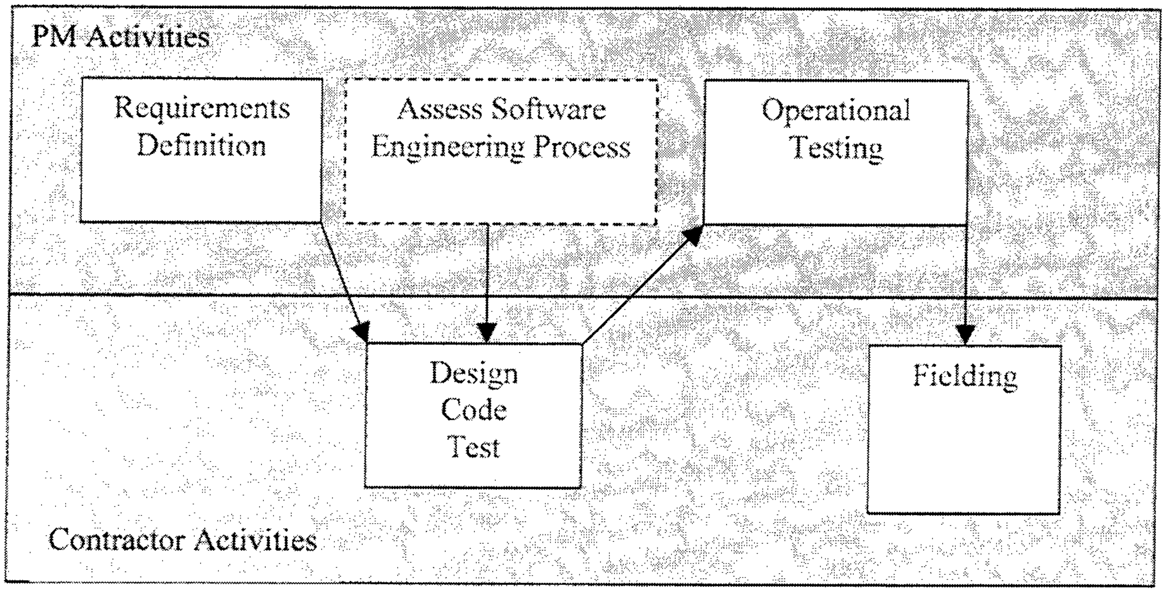
Table 3. CAMIN Version 8.0 Lines of Code

Workstation administration is labor-intensive. Due to the frequency of problems, sites assign a local workstation administrator at each installation. These administrators are not always well trained or qualified to do the work, but the individual provides CAMIN Managers with a single point of contact to send documentation and updates, as well as a single point of responsibility for monitoring the configuration of workstations. This effort is necessary because users and administrators load unapproved software and hardware, forget passwords, delete or overwrite files, dynamically linked libraries and registry, and otherwise create an environment that prevents CAMIN functionality on the workstation. DCE facilitates system functionality by preventing connectivity unless there is synchronization between the workstation and the server. Lack of workstation use to access CAMIN can cause the clock to lose synchronicity with

the server, and require the user or local administrator to clobber and reconfigure DCE before using CAMIN applications.

d. Upgrades

The Maintenance and Requirements Upgrades include the areas of Design and Development, Code Writing, Testing, and Fielding. These upgrades occur in the form of version changes or patches. Version changes have historically occurred one or two times per year, and patches may occur more frequently. The Problem/Change Request (PCR) Database keeps track of all PCRs, classified by CCB disposition, magnitude of difficulty, ability to accomplish in a patch, and whether the PCR is associated with a version or a patch. Version Upgrade Process: The process starts with a change being approved by the CCB, and with related requirements for design or software changes. The PM determines which changes are needed, and initiates funding requests and a contract modification to implement the upgrade. Award of the contract modification includes a negotiation of the exact number and combination of PCRs, and the schedule to accomplish these system modifications. The contractor proceeds with design and development, code writing, and then performs testing. The contractor provides a test area for the Government to perform acceptance testing. After Government acceptance, the contractor publishes and mails CDs, installation manuals, and Version Description Documents (VDD) to workstation administrators for dissemination and oversight of the installation.



[Developed by Researcher]

Figure 6. CAMIN Maintenance Upgrade Activities

Patch Process: An urgently needed change to the system typically drives the patch. The PM decides candidate PCRs, and then authorizes the contractor, through the Procuring Contracting Officer, to implement the patch. The contractor and PM test the patch, then make the patch available to download and install from the web site. The local workstation administrators are responsible to ensure that the workstations under their purview have the new patch installed.

5. CAMIN Metrics

The CAMIN PM uses metrics to assess the program in terms of schedule, budget, and functionality requirements. The primary sources for these metrics are the contractor output, PM data from internal documentation, and the CAMIN system itself. The metrics

used are those easily accessible, those that are most obvious, and those that are required by upper management.

The support contractor tracks additional metrics that address requirements, program management, quality assurance, configuration management, training, peer review, critical resource, maintenance, development, and intergroup coordination. Appendix D provides a more detailed list, summarizing the metrics tracked by the contractor. Documentation and process quality are very important to the contractor's internal procedures. Their activities for the CAMIN program are qualified for between level 3 and 4 on the Software Engineering Institute (SEI) Software Capability Maturity Model (SW-CMM) evaluation.

The PM uses metrics that address areas that are common with the contractor. In addition, the PM uses metrics to address contract management. The PM generates a weekly CAMIN report to measure and report progress of the CAMIN data against Treaty and destruction goals. The data in the weekly report provide measures of data and the number of transactions against those data for the weekly period. Another way that performance is measured, is to annually review the programmatic goals in the business plan against accomplishments for the year.

The CAMIN program generates and utilizes metrics summarized in Table 4. The selection and application of appropriate metrics requires organization and thoughtful consideration. Each metric consumes time for collection, reporting, and analysis.

Metric	Purpose
Funding Obligated and Disbursed	Tracking funding helps to schedule work, to help predict future shortcomings, to manage work force issues, and to help assess money expenditures.
Schedule	Tracking schedule helps to meet user needs and to control costs.
User Help	Tracking the type, duration, and source of user help calls has benefited the program through identifying systemic problems. Evaluating help-line calls can drive a new training need or drive a change to the CAMIN design. Particular users or user types may need additional training. The user manual may need improvement.
Data Interventions	Data interventions are often expensive, time-consuming, and risky to the database. Those that are most skilled in database administration perform data interventions. Evaluation identifies systemic problems that may drive changes to user training, user manual, and/or changes to the system software.
Percent Completion	When developing a new version of software, track the level of completion of each phase.
Training	Training factors tracked include student list, types of training given, and feedback reports from trainees. These measure the adequacy of training through feedback and repeat trainees.
Requirements	A database tracks all existing requirements for CAMIN. If a requirement was completed, the database retains the date/version of completion. This metric provides a series of historical baselines, and tracks remaining work.
PCR	A database tracks PCRs for the CCB. This maintains the list of the PCRs, documentation of CCB discussion or decision on the action, and other related data elements.

Actions	A database tracks the actions from meetings, the individual, or organization responsible, and completion information. This provides a measure of activity that affects cost, schedule, and performance of CAMIN.
User List	A list of users, their passwords and permissions, are tracked, and periodically assessed to keep the user list limited to those who need permissions, and to limit the permissions to only those needed. This control protects the CAMIN system and its data.
Hardware/ Software List	A list of program hardware and installed software helps to ensure that workstations are maintainable, and that they have the correct version of CAMIN and COTS software.
User Accounts and Logins	The CAMIN software has an application that provides reports of user accounts and logins. Through this, system usage and application usage is tracked. The data helps to determine if a users accounts or permissions need modification. The data can help determine if applications are under or over utilized.

[Developed by Researcher]

Table 4. CAMIN Program Management Metrics

B. CAMIN AND THE ACQUISITION PROCESS

CAMIN is in the Operations and Support Phase of the program. For automation systems, this phase corresponds to fielded software systems. Like typical software systems, the CAMIN goes through an iterative process of development, production, and deployment of system maintenance upgrades and enhancements. This process of cyclical changes to the system is often confusing to anyone that is not familiar with software systems.

The DoD Acquisition Model (Figure 7) shows the basic phases of the acquisition process. This section provides a brief description of the history of the CAMIN Program

and significant events within the acquisition process framework. It is important to study the history of CAMIN versions in order to understand that CAMIN development has continued well into the PDSS phase. Each version update has added to the functionality of CAMIN to meet the original functional requirements, while making incremental enhancements to the functionality based on user needs. Version upgrades continue to be required through the life of the system.

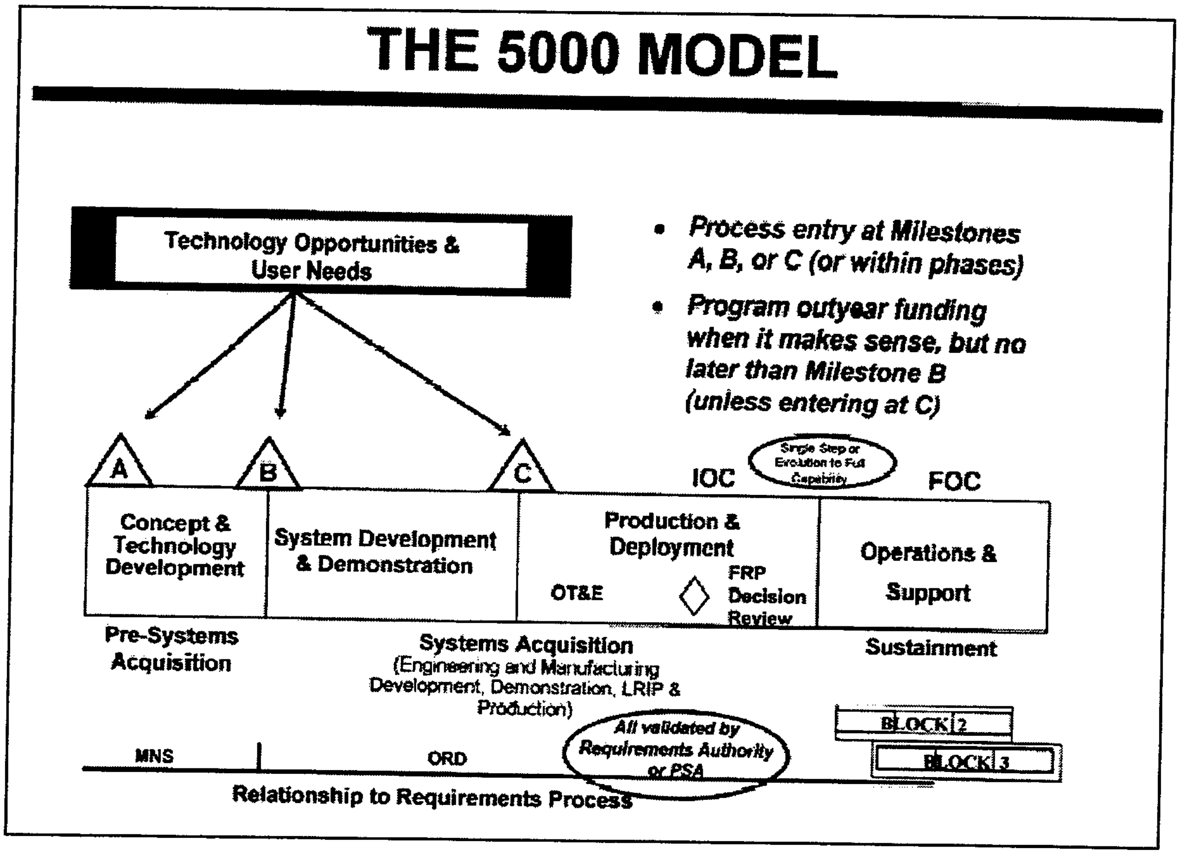
1. Concepts and Technology Development

The developers spent little time on the Concept and Technology Development for CAMIN. In 1994-95, the DoD created an urgent requirement to develop a system for tracking, verifying, and reporting Chemical Treaty required data. The basis of this urgent requirement was the uncertainty of when the United States Senate would ratify the first of the pending chemical treaties. While common, urgency is never a good environment to develop software, and this, ultimately, caused long-term problems.

The CAMIN developer, the Defense Threat Reduction Agency, then Defense Nuclear Agency, had an existing contract with TRW, then BDM Federal, to develop the Compliance Management and Tracking System (CMTS) for all DoD Treaty data.

The CAMIN design uses the experience of two prior existing systems. The CAMIN system was initially an add-on to CMTS. Therefore, developers used CMTS as the template for system architecture and initial design of CAMIN. The other system involved in the development process was the existing Accountable system, the Toxic Chemical Munitions (TCM) Database. The TCM was insufficient to meet Treaty needs, and was not robust enough to continue operation as destruction began and transactions

increased significantly. The TCM design was very limiting. The language was dBase III, and it used a series of stand-alone workstations. TCM users transferred local accountability data to the Accountable officer periodically over secure phone lines.

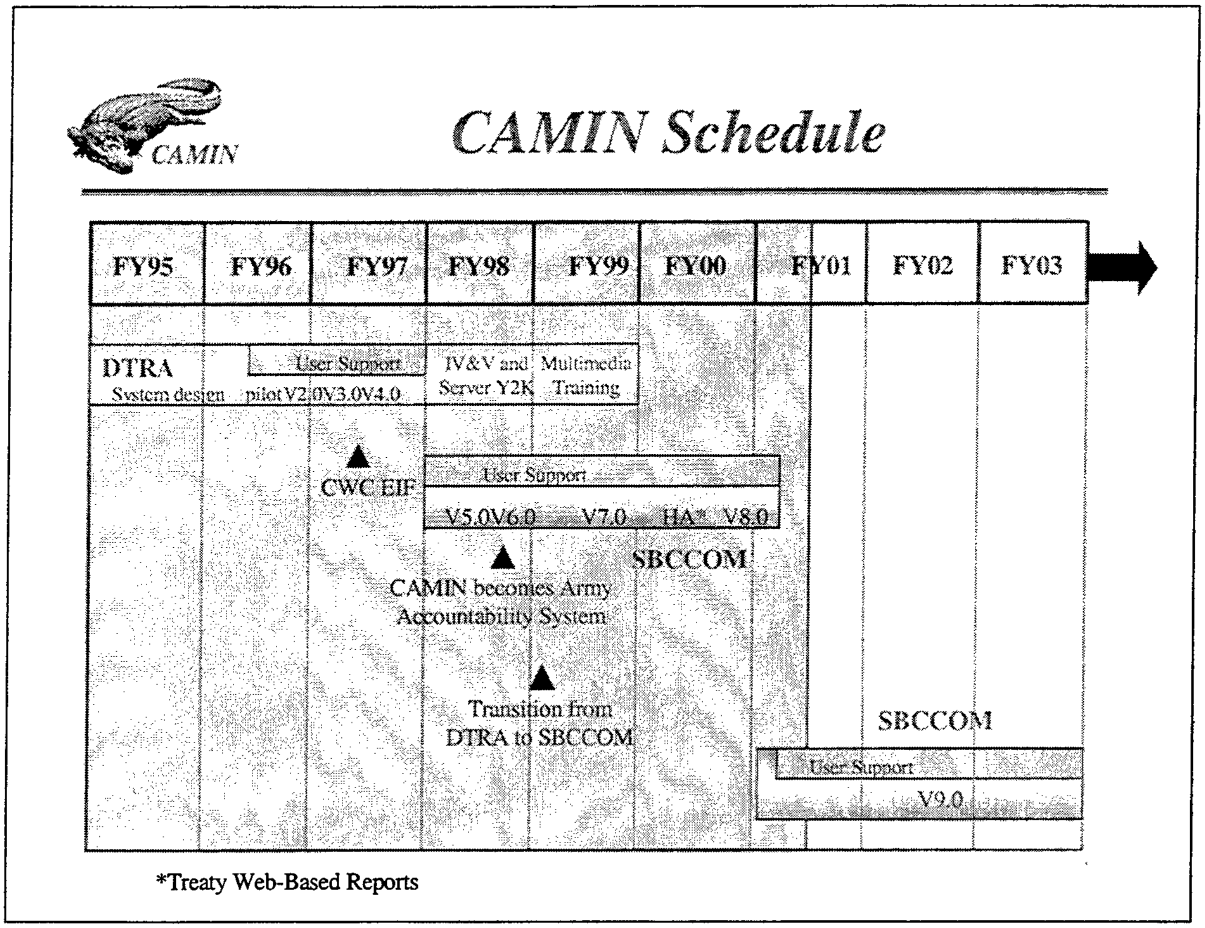


[From Ref. 8]

Figure 7. The DoD 5000 Series Acquisition Phases

When the developers began working to merge the architecture of CMTS with the functionality of TCM, the results became very complex. Due to complexity and unique accountability requirements, the system concept eventually grew into a system that is

completely separate from CMTS. CAMIN was now ready to enter the System Development and Demonstration phase.



[From Ref.14]

Figure 8. CAMIN Program History

2. System Development and Demonstration

The System Development and Demonstration of the CAMIN included basic software development, with user involvement. The developers held a series of User Group meetings to discuss concepts and ideas. The developers created a proposed

architecture and presented it to users. They also presented sample screens and views to show the users how the system would look.

The urgency for Treaty needs led to an interim goal for CAMIN to provide only minimal functionality. In this first version, applications had no inherent process other than to convert inputted data into the required format. As time passed and managers grew more frantic, the Treaty hierarchy decided to release a first version that addressed only the CW and accountability. This decision resulted in the delay in full meeting requirements for CWPF and Permitted Activities applications until later versions.

The development of CAMIN was truncated, and Version 1.0 fielding occurred at three beta sites. Version 2.0 contained additional requirements and incorporated user feedback from Version 1.0. The transition from R&D funding to primarily O&M funding occurred in this timeframe.

3. Production and Deployment

Developers fielded Version 2.0 to all user sites. In versions 3.0 and 4.0, the developer included additional functionality. With the new functionality, the system came closer to meeting the original system requirements. With version 5.0, the transition process began with the movement of contract management activities from the Defense Threat Reduction Agency (DTRA), as the Research and Development agency, to SBCCOM for Operations and Maintenance. The transition process included a full Independent Verification and Validation Test (IV&V), using an external agency to design and perform the test. The schedule in Figure 8 shows the transition period, spanning from FY 98 through FY 99. During transition, SBCCOM awarded a sole source contract

to TRW for O&M of CAMIN. The developer transitioned the system in December 1998, with a couple of outstanding actions. Development of Computer-Based Training (CBT) CDs by DTRA enabled multimedia system training. In addition, DTRA would also fund the required testing to accomplish Y2K requirements imposed by DoD. Once CAMIN replaced TCM to become the Army accountable system in 1998, storage funding became part of the overall funding for the management of CAMIN.

4. Operations and Support

The Operations and Support phase of CAMIN encompasses a wide variety of program management activities, as described in this document. In addition, new software versions continue to meet the changing needs of the users, the hardware/software/network environment, and the DoD. System and data users continue to identify new and refined requirements for CAMIN functionality. Changes included new data output or input formats. These types of changes to requirements can affect the structure of the database and cause significant revisions to the system. The environment changes also drive CAMIN changes. Firewalls and other network issues can require frequent system revisions. It is not practical to adopt new software versions as soon as the industry makes them available, but the CAMIN system must eventually migrate to receive the support ,and to remain compatible with the external environment. The DoD has recently imposed significant security-related policies that affect the CAMIN workstations, server, and web site, as well.

The CAMIN Version 8.0 fielding occurred in FY01. A significant list of approved PCRs is ready to incorporate into the next version of CAMIN. Once funded,

the program to reduce the dependence on CAMIN workstations by developing and providing web-enabled applications for data entry and data access users can begin.

C. AREAS OF INTEREST FOR CAMIN PROGRAM MANAGEMENT

To summarize this chapter, the major issue areas of CAMIN program management provide a basis for analysis of metrics. The issues listed in this section are interrelated, but each is a distinct area for program management concern. It is important to view program management metrics in terms of program issues. The selected metrics must address all of these key areas.

1. Funding

As previously discussed, funding levels for the CAMIN Program have been unpredictable, but have reduced over the last two years. The funding deficit and uncertainty cause significant problems for the CAMIN system. Improved communication and controls mitigates the funding problems. However, measures of funding are needed to address the following areas: understanding the funding needs based on program management requirements, communication of funding justification to fund managers, and funding availability to meet program requirements.

2. System Availability

System availability is critical for two key reasons. First, users must be able to access and update CAMIN data in support of short-notice Treaty inspections. Availability is critical to enable users to accomplish timely input of inventory transactions. Availability is dependent on connections, configuration, and power. To

meet PM requirements for system availability, areas that need to be addressed are: system software capability to perform customer requirements, power to the system, connectivity through the network, firewall, and other security systems, workstation configuration and user account maintenance, and system maintenance to keep the system running efficiently.

3. Data and Output Accuracy

The critical missions of Treaty and accountability drive the need for data accuracy. Treaty requires accuracy to help maintain U.S. integrity with the international inspectors. The accountability mission requires a system with substantial data protections and an audit trail, with the aim of achieving 100% accuracy. Accuracy relates to the system design, to the user permissions, and to the competency of system users. An oversight organization also needs to periodically audit the data. In this case, both Treaty and accountability should audit data for their respective requirements. Factors in this process are listed here; training of users, help line for users of the system and data, user manuals, ease of use and data protections in CAMIN software, data audit by cognizant organizations, and data interventions to correct user errors and to perform mass changes to system data.

4. Experienced IT Support

Retention of IT support staff is important to reduce the extended learning curves associated with working on complex systems. The program's ability to retain developers and maintainers of CAMIN is dependent on consistent funding, consistent work, and

overcoming technological challenges. The CAMIN program has sufficient work requirements if funding were available. Consistent workload through iterative maintenance activities can help to retain an experienced workforce. However, maintaining the consistent workforce involves leveling of tasks to achieve a consistent level of work, challenging the staff by using current or leading technology, and using a contract vehicle that provides adequate funding and work levels.

5. Requirements Changes

The area of requirement definition and associated changes is critical to continued CAMIN functionality and user satisfaction. Through the history of CAMIN, these factors have driven the program changes. The hardware and software require periodic upgrade to maintain continued operation and maintenance. The users and customers have added requirements and enhancements each year to reduce processing time, reduce errors, and improve the system. In order to assess revisions to system requirements, the following areas must be addressed: changes to COTS and hardware, network changes, state of the art technology and architecture, and evaluating changes in terms of time to accomplish change, and the priority and complexity of these changes.

III. DATA PRESENTATION: CANDIDATE METRICS

Metrics have become commonplace in program management, and metrics tools are available through literature and through case analysis. In this chapter, data collection and analysis provides a thorough list of the types of metrics that may be appropriate for CAMIN and other systems in the PDSS phase. This chapter also contains a discussion of the types of metrics that managers may use in Management Information Systems in general. The term "Management Information Systems" refers to systems designed to automate business processes, rather than software systems embedded in weapon systems, vehicles, and the like.

The metrics for management of software that exist in the current literature are oriented toward the development of software, rather than sustainment of deployed systems. When the CAMIN system undergoes its iterative software changes, the development-related metrics remain valid. However, CAMIN is a deployed system, and may warrant measurement in terms of customer satisfaction, user accessibility, including readiness and downtime, help desk support, and other feedback tools. Therefore, Chapter III also discusses of the types of metrics that Program Managers typically use in the management of fielded systems.

The discussion of metrics in this chapter considers both DoD system metrics and commercial metrics. Use of commercial best practices is a tenet of the DoD 5000 guidance on acquisition reform within DoD, and so consideration of Government and commercial practices should help to arrive at the optimal metrics selection. The chapter

also examines the metrics of other fielded software systems that are comparable to CAMIN, based on the life cycle, funding, management style, and type of system.

A. SOFTWARE METRICS

The Clinger-Cohen Act, otherwise known as the Information Technology Management Reform Act of 1996 [Ref. 5], provides tools for management of IT within the U.S. Government. These tools help to manage funds and contracts to acquire IT more efficiently by providing flexibility in the acquisition process. The Clinger-Cohen Act requires the use of measures for software acquisition and management specifically, as follows:

> The head of an executive agency shall (3) ensure that performance measures are prescribed for information technology used by or to be acquired for, the executive agency and that the performance measurements measure how well the information technology supports programs of the executive agency.
>
> [From Ref. 5, Section 5123(3)]

To establish valid metrics for software development and production, managers need tools to establish overall process quality. PMs can require that software developers certify the quality of the software production process through standards established in ISO 9000 and the SEI Software Capability Maturity Model (SW-CMM) [Ref. 20]. Yet, software performance parameters are difficult to define and measure, as the definition of parameters for a system changes based on platform, programming language, and user interface. Additional factors in software measurement include the fast-changing environment in which the software must remain functional. The changes in the platform

and networks are fluid. Requirement creep is also more common with software-intensive systems than with strictly-hardware systems. In addition, integration testing often requires completed software and hardware. The metrics associated with successful systems development projects in successful companies are those that deliver on schedule, relatively close to budget, and with high levels of quality and reliability.

1. Management Information Systems

This thesis makes a differentiation between Management Information Systems and other systems. Systems compared here have more similarities than differences, especially when analyzed within the DoD acquisition framework. However, the differences have an effect on decisions about how to plan for and to manage these systems. Management Information Systems require frequent changes due to dependence on platform and COTS. Table 5 shows a comparison of the key program management parameters for each of the three program types. These differences are generalizations, but are typically true.

Table 5 shows that requirements are very unstable for software systems, relative to hardware. External sources, such as environment changes, user needs, COTS changes, and platform changes drive modification to the system requirements. Development is iterative for software-based systems. Complex systems may experience iterative development for many years. Additionally, development-like activities occur as part of the process to perform maintenance upgrades to the system to meet changing system requirements.

	Management Information Systems	Embedded Software Systems	Standard Hardware Systems
Requirements	Changes through the system life, driven by platform, environment, users	Changes through the system life, driven by users and interface (more stable platform and environment)	Theoretically frozen at ORD, really frozen at materiel release
Development	Iterative, costly, through the life of the program, dependent on experts and creativity	Somewhat iterative, but limited by hardware platform	One time- Waterfall to Production
Testing	Beta and IV&V	DT and OT	DT and OT
Production	Print CDs	Install in production hardware	Production may occur over multiple years
Fielding	Mail CDs and instructions, or make available over Web site	Concurrent with fielding of platform	Fielding may occur over multiple years
Technical and Engineering Data	Source Code with comments, Database Dictionary	Source Code with comments, Database Dictionary, interface documents	Drawings and Specifications
Training and Manuals	Required and updated about annually with each version	Required	Required
Operations and Maintenance	Intense, with revisions required about annually	Concurrent with periodic platform maintenance	Periodic

[Developed by Researcher]

Table 5. Comparing Management Information Systems to Other Systems

Testing for Management Information Systems can often take place in an office environment. Through beta testing, users provide feedback on the initial system functionality and operations.

Production for software is simple. Once the version testing is complete, production may include printing Compact Disks (CDs) with the installation code loaded. Changes to Management Information Systems are relatively easy to field. Fielding often involves the relatively simple process of printing and mailing CDs with installation instructions. Unlike hardware, software changes are easy to code and field, as well. The limitation on system upgrades comes primarily from the areas of testing and documentation. These processes are more time-consuming and costly for software than for hardware. Additionally, the technical and engineering data are different for software and hardware.

For Management Information Systems, there is a greater flexibility in the areas of training and manual generation, revision, and support. Training can take place on a computer system with only a simple interface, and for embedded software or hardware, modeling and simulation can provide a realistic training environment. However, training is not complete without spending time on the actual hardware system.

The majority of activities involved in the O&M of software requires technical expertise, experience, and directed knowledge of the system architecture and code. Data administration and software changes introduce the most risk when performed by less skilled personnel. There are several levels to perform maintenance of most hardware

systems, and the maintainers can more readily understand the system through technical drawings and other documentation.

2. Department of Defense Requirements for Software Metrics

The DoD and its Services have been in the forefront of automation and software development since the first computer was developed. For example, the DoD sponsored the early development of supercomputers to calculate ballistics, the computer language ADA, and the Oracle database. In 1992, DoD recommended the four Basic Measures for software systems shown in Table 6.

Unit Of Measure	Characteristics Addressed
Counts of physical source lines of code	Size, progress, reuse
Counts of staff hours expended	Effort, cost, resource, allocations
Calendar dates	Schedule
Counts of software problems and defects	Quality, readiness for delivery, improvement trends

[After Ref. 2]

Table 6. DoD Recommended Measures from 1992

The DoD requirements for software measures established in this 1992 document did not change significantly when addressed again in 1996. In a 1996 policy memo [Ref. 17], OSD requires that, at a minimum, software metrics should address the following six areas:

1. Schedule and progress regarding work completion,

2. Growth and stability regarding delivery of the required capability,

3. Funding and personnel resources regarding the work to be performed,

4. Product quality regarding the delivered products,

5. Software development performance regarding the capabilities to meet program needs, and

6. Technical adequacy regarding software reuse, ADA, and use of standard data elements

The U.S. Army has developed a program called the Software Test and Evaluation Panel (STEP) to address software metrics and their use. DA Pamphlet 73-7, dated 25 July 1997 [Ref. 10] provides the published list of Army Software Metrics. Table 7 summarizes the list of metrics included in the document. The Air Force also recommends the Army STEP Metrics for program management of software [Ref. 9].

The STEP Metrics use many standard software metrics, adopting best commercial practices. These metrics are inclusive of fielded systems, including measures of mean down times, fault profiles, and reliability. The three categories for metrics are management, requirements, and quality.

	METRICS	OBJECTIVES	MEASUREMENTS
MANAGEMENT CATEGORY	Cost Schedule Computer resource utilization Software engineering environment	Track software expenditures Track schedule adherence Track planned and actual resource use Quantify developer software engineering environment maturity	Dollars spent vs. dollars allocated Milestone/event slippage Percent resource capacity utilized Computed maturity level
REQUIREMENTS CATEGORY	Requirements traceability Requirements stability	Track requirements down to code Track changes to requirements	Percent requirements traced Number of requirements changes
QUALITY CATEGORY	Design stability Complexity Breadth of testing Depth of testing Fault profiles Reliability	Track design changes Assess code quality Track testing of requirements Track testing of code Track open vs. closed anomalies Assess software mission failures Measure down time	Stability index Complexity indices Percent requirements tested Percent requirements passed Degree of code testing Number and types of faults, average open age Mean time between failures Restoration times

[From Ref. 16]

Table 7. Army Software Test and Evaluation Panel Metrics

Management metrics address the basic areas of cost and schedule. Further, the maturity level is an assessment of the processes used by the software organization, in accordance with the SEI SW-CMM. Within the requirements category, traceability and stability establish quantitative values for the requirements generation and change processes. The quality of the system provides a series of measures that help managers to assess how well the system functions through changes, complexity, testing, and measurement of failures.

3. Commercial Software Metrics

Research shows that published metrics for software systems support the development phase, without specifically addressing support of fielded systems. Commercial software metrics do not introduce additional metrics beyond those used for DoD. Therefore, the set of software metrics established for DoD and the Army is inclusive of the typical measures and tools that commercial industry uses for management of software programs.

B. FIELDED SYSTEM METRICS

Fielded systems measurement should address issues related to continuous management of the system, and issues relating to the use of the system. These metrics include those that come directly from the system customers. The list of customers includes upper management, those involved in funding, and those who perform data input, those who access system data, and the system maintainers and administrators.

Aspects of use that merit consideration for metrics are user satisfaction, response time, failure rates, equipment, spares and replacements, and quality problems.

The measures of fielded systems should provide specific outcomes. Cost drivers related to system operations are key areas that warrant measurement. Cost drivers include user help and training, maintenance of software, (e.g., correction of defects, enhancements), hardware and software purchases, and data maintenance and administration. These cost drivers can help to develop metrics that continuously diagnose problems and assess the outcomes of corrective actions.

1. Department of Defense Logistics Metrics

The DoD establishes metrics for its fielded systems based on established criteria. The basic goals with fielded systems are to maintain system readiness through maximizing availability and minimizing maintenance factors.

The DoD environment differs significantly from the commercial environment, because systems are in use for much longer in the military environment than in the commercial environment. These aging systems require more frequent maintenance activities. Maintenance on these older systems is more difficult, requiring better records and repair parts. The short life of commercial automation hardware and software, and the associated support cycle are not consistent with the military concept.

Table 8 provides a list of the Objectives and Performance Measures that are included in the DoD FY 2000 Logistic Strategic Plan [Ref. 7]. These measures are part of the overall logistic plan for all fielded systems within DoD. Readiness is a primary concern for logistics, and most of these DoD measures relate to readiness. In general, the

DoD is concerned with having systems that are available and perform well, while controlling costs.

The objective to improve strategic mobility to meet Warfighter requirements is to help achieve readiness from mobility of assets. Mobility is only an issue for Management Information Systems in the rare case where a site needs a node, workstation, and connectivity, urgently. Having assets available to address these urgent requirements can satisfy another objective, to fully implement joint Total Asset Visibility (TAV) across DoD. Knowing the location, configuration, and usage of workstations and user accounts is the key to meeting this objective for Management Information Systems.

OBJECTIVE	MEASURES
Optimize support to the Warfighter	Measure: Attain the specified percentage of Level "A" weapon systems meeting their targeted Mission Capable (MC) Rate through FY 2006. Develop a documented baseline of applicable Military Service MC rates by the end of FY 2001. Establish target MC rates for the end of FY 2006, and track progress in attaining these targets (i.e., the percentage of increased/decreased MC rates) annually beginning at the end of FY 2001. The Military Services will develop the capability for quantifying the actual and target MC rates based on individual weapon systems, weapon system categories or Service composite, as appropriate, to provide meaningful performance information. The Defense Logistics Agency will develop the capability for reporting its Customer Wait Time (CWT) baseline and annual progress toward the Defense Logistics Agency FY 2006 CWT target, by Service or consistent with the Services' weapon system categories. Each Component will report its composite progress against its target(s) annually, beginning at the end of FY 2001.
Improve strategic mobility to meet Warfighter requirements	Measure 1: By the end of FY 2006, achieve a cargo airlift capacity and sealift surge and afloat pre-position capacity to meet the validated requirements in the current Mobility Requirements Study. Measure 2: Develop a measurement plan and goals for mobility infrastructure and mobility process improvements by the end of FY 2001. Achieve those goals by the end of FY 2006.

Implement Customer Wait Time (CWT) as the DoD logistics metric	Measure 1: Develop the process for definition and measurement of Customer Wait Time (CWT) by the end of FY 2001. Measure 2: Fully implement CWT measurement for 100 percent of all selected segments by the end of FY 2006.
Fully implement joint Total Asset Visibility (TAV) across DoD	Measure: Determine user/business methods, asset information requirements and associated measures by the end of FY 2000, implement 100 percent of requirements by the end of FY 2006.
Reengineer/ modernize applicable logistics processes/ systems	Measure: Develop Component logistics processes/systems modernization plans by the end of FY 2001, and increase the proportion of modernized logistics business systems according to those plans by the end of FY 2006. The Military Services, the Defense Logistics Agency, and the U.S. Transportation Command will develop the capability for quantifying the percentage of logistics and related Automated Data Processing (ADP) systems modernized using implementation status as of the end of FY 1999 as a baseline. For each major system undergoing modernization, track annual progress against an FY 2006 target percentage. Each Component will report its composite progress against its target annually beginning at the end of FY 2001.
Minimize logistics costs while meeting Warfighter requirements	Measure: For selected fielded weapon systems, reduce the logistics support cost per weapon system per year compared to FY 1997 baseline as follows: 7 percent by FY 2000; 10 percent by FY 2001; and a stretch target of 20 percent by the end of FY 2005.

[After Ref. 7]

Table 8. DoD FY 2000 Logistic Measures

These measures, identified in Table 8, correlate to Management Information Systems, two of which are strongly related to system readiness and availability. These are: 1) Optimize support to the Warfighter and 2) Implement Customer Wait Time (CWT) as the DoD logistics metric. For Management Information Systems, availability and readiness are measured in terms of system down time, to include server, workstation,

and connectivity. Measuring mission capability for Management Information Systems also includes system down time and the processing speed for the system.

To reengineer and modernize applicable logistics processes/systems is to establish and maintain a system of goals and measurements for the Management Information System. Programs can achieve this through development and periodic assessment of business plans, schedules, objectives, and measures.

O&M funds are the typical type of funding used for logistics costs, and O&M dollars are a scarce resource within DoD. Once a system is fielded, the manager's primary objective is to minimize logistics costs while meeting Warfighter requirements. The logistics costs for fielded Management Information Systems includes maintenance of all user requirements, upkeep of the system, and iterative maintenance upgrades. Revalidating the validity of requirements helps to control costs. Another cost control measure for logistics is consideration of the system architecture. Application of new technologies emerging from the IT industry can also help reduce logistics costs to fielded software systems.

2. Industry Measures for Fielded Systems

The basis for most measures that industry uses for fielded software systems is the ability to earn profit on sales of future end items or components, to improve return on investment. Industry wants to keep the customer satisfied, if the satisfaction can lead to future purchases of the end item or related items. In commercial industry, companies also want to measure satisfaction in an effort to improve the next product version enough to increase customer loyalty and, consequently, improve future sales.

In order to measure and improve customer satisfaction for fielded software systems, it is essential to understand what factors actually drive customer satisfaction. These drivers determine attributes to measure and functions or processes to improve. The concept of customer satisfaction in industry determines future customers for the product or service. In DoD, most users do not have the choice to "shop around." The NICP and Treaty community have selected CAMIN as the system that the sites must use. Nevertheless, assessing and improving customer satisfaction is beneficial to maximizing efficient and timely use of the system by existing users. Customer satisfaction is a broad area, encompassing these four dimensions of program management: system performance, customer expectations, customer perception of his or her interaction with the PMO, and problem resolution.

C. CASE INTERVIEWS

Comparing other similar fielded software systems to CAMIN yields insight into the program management measures that managers typically use. The following two DoD systems have characteristics in common with the CAMIN System. These systems are the Engineering Data Management (EDM) System and the Federal Emergency Management Information System (FEMIS). An analysis of these systems provides information concerning the systems, including a description, their unique parameters, and the metrics used in program management of these systems.

1. Engineering Data Management System

(Ref. 1)

a. System Purpose

The Engineering Data Management (EDM) system O&M resides within SBCCOM to maintain and provide access to all technical data for the command Research, Development, and Acquisition Center. The purpose of the EDM system is to manage SBCCOM engineering data. EDM is a Product Data Management (PDM) system, and PDM is the commercial name for the generic family of products to manage engineering data. Data includes the engineering drawings and specifications and the relationships among those documents to include configuration management relationships. The system controls data entry, data access, and associated user permissions.

b. System Description

The EDM is both thin client and a client-server system. The user interface is completely based on thin client architecture. Thin client means that no software code or data are stored on the client workstations. The client-server system predates the thin client, to reduce operating cost and complexity. Once thin client is available for all user needs, the client-server system serves only system administration and data administration functions.

For a thin client system, the workstation requirements are very basic. These COTS software packages are required: a 128-bit encrypted web browser, Adobe Acrobat Reader, WordPad or Unix text reader, and a raster reader. The imager for the raster reader is available free from the Army. The PDM COTS product used in EDM

performs these functions. It manages interfaces and data access for the Graphical User Interface (GUI) system administration tool. It manages the vault and the storage media where images are located. Finally, it manages the Oracle database that retains the Meta data for the documents stored in the system.

The EDM uses three different types of thin client interfaces. First, the COTS thin client interface provides all the same capabilities as the full client system, with the exception of system administration tools. Permission and group controls permit operation of the interface. Second, EDM has a custom interface that provides a simplistic view and access to the system. The user-based capabilities of the web interface are the same as the full system, but the limited features simplify navigation within the system, and users find this interface easier to learn and use. Systemic user problems drive the need for this interface. When users are not accessing the system frequently, the users fail to gain the familiarity required to use the more complex version. The third system access portal is another custom interface. This interface is very specialized, providing access to selected users for assignment of drawing numbers. Drawing numbers are an index field in the system database, and the controls must exist for assignment of these numbers.

EDM also has a workflow management tool as part of the PDM COTS package. The workflow management tool automates the engineering data processes. It tracks the processing and status of the necessary events to generate and release new data.

The user community for EDM is limited to DoD employees and contractors that require access to the data. The acquisition community uses the system to provide the baseline for procurement of end items and of spare and repair parts. The

engineering community uses it as a repository for designs, reference source for design improvements and new developments. Engineers also use the system to provide information in support of investigations of field failures. In the current configuration, the system is simple enough that no user manuals or formal training of the general user group is required. The EDM PM operates a help desk, and provides straightforward written user procedures, upon request.

c. *System Metrics*

The PM for the EDM has no formal program for metrics, but uses the parameters described in this section for measuring system success. EDM measures and assesses customer response. The PM collects these data regarding the satisfaction of system users, mainly through interpretation of help desk calls. The help desk calls may indicate a systemic problem, operational problem, or training problem.

Another measure is performance against operational requirements. Services provided are continuously improved based on the PM vision of what a PDM system should do in the current environment and what tools are available to do them. A group of PMs is performing similar tasks from other AMC Major Subordinate Commands (MSCs). The PM for this system uses output from the group to codify the vision. The result is a performance specification for the Automated Configuration Management System (ACMS) [Ref. 1].

In the area of resource management, EDM assesses costs and bill-payers. The EDM PM must budget well in advance of the actual need. During each year, the PM uses previously budgeted funding to contractor consultant hours to fix bugs and

implement needed enhancements. Historical data helps to estimate needed funding. Annual operating cost is approximately 20 percent of the initial cost to field an operational system. This figure correlates to the annual maintenance fees charged by most COTS manufacturers.

The EDM has two types of paying customers. Project teams that are requiring engineering data to be stored in the repository pay variable costs. The SBCCOM RDA Enterprise pays the fixed costs, so that the engineering and acquisition community can use the system to access the data. These customers are widely satisfied with the system, and budget to maintain the system at required levels.

Quality is another concern of the EDM program manager. The PMO tests each software change, and performs troubleshooting when a problem is suspected. They maintain a test bed to facilitate regular testing. Testing methods consist mostly of testing various Use Cases and reporting problems back to software consultants for correction.

2. Federal Emergency Management Information System

(Ref. 12 and 13)

a. System Purpose

The SBCCOM and the Federal Emergency Management Agency jointly developed the FEMIS. The FEMIS is an integrated system that provides planning, coordination, response, and exercise support for emergency management personnel.

During an emergency response, the FEMIS users retrieve and execute plans created under non-emergency conditions. FEMIS uses real-time data from outside sources, such as meteorological monitors. To support the decision-making process,

FEMIS provides these outputs to the user: resource tracking, task lists, contact lists, event logs, status boards, hazard modeling, and evacuation modeling.

b. System Description

Local, state, and Federal emergency management experts developed the requirements for FEMIS. Users were actively involved in the prototype reviews, testing, and setting priorities. Continuing development is the result of user input and review. FEMIS meets Federal and industry open systems standards. The system architecture consists of a suite of COTS software products, including ArcView, Oracle, and Microsoft Project. The U.S. Government provides the hazard analysis and evacuation models.

The system platform is client-server based to support multiple users, distributed data, and multiple operations centers. FEMIS uses a UNIX central data server and personal computer clients with Windows NT. The size of the FEMIS is approximately 1.25 million SLOCs. The system has up to 350 users. Leased lines connect system nodes. The system uses a LAN connection from client to server.

The FEMIS system development is recent. Requirements definition occurred in 1993. The first system fielding occurred in 1995 as version 1.1. General system fielding occurred in 1999 as version 1.4.5. The current version is 1.4.7. Maintenance releases, with enhancements, occur about every 8-12 months.

The PM for FEMIS is evaluating the conversion of the user interface to a thin client structure. A conversion would enhance the FEMIS, reducing firewall issues, improving system accessibility, and saving life cycle costs.

c. *System Metrics*

The FEMIS PM uses the Software Enhancement and Problem Report (SEPR) database, maintained by the contractor, to measure the system. The reports track SEPRs by three aspects: severity, time to close, and rate in versus rate closed. The SEPR process introduces all enhancements to the system. The PM uses the following two measures for tracking SEPRs: severity measure, which is commercial practice, and measure of DoD priority.

D. PDSS CANDIDATE METRICS

This section provides descriptions of the candidate metrics for fielded software systems. Table 9 summarizes the metrics from this chapter, and cross-levels among the possible sources of metrics, to include: 1) software metrics, 2) fielded system metrics, 3) metrics derived from the case analysis, and 4) CAMIN metrics. The metrics collected vary in scale, and major metrics encompass minor metrics. The combination of metrics from these various sources enriches the definition of the metrics with respect to reality in a PDSS environment. This section also discusses each metric and its usefulness. Table 10, presented near the end of this chapter, encapsulates the detailed list of PDSS candidate metrics and the associated measures, derived from of this research.

1. Management and Planning

Measuring and tracking costs and schedule are important to ensure that a program remains within existing funding and meets schedule requirements. These measures help the PM to predict cost and schedule of the fielded software systems for future years, and to help identify areas for cost control. The funding rates identify problem areas and

opportunities for diversion of funding from lagging areas to more urgent and important ones. Counting hours expended is a measure of trends and assessment of efficiency. Software design and development is an art as well as a science, and writing new code may not adhere to a strict schedule. As a result, slips in schedule may affect available funding.

The PM uses measures to assess the cost expenditures for software tasks, compared to the initial cost estimates. Program cost measures assess trends and improvements, and provide data for future cost estimates. PMs need to track obligated and expended costs against progress and number of defects. Charts and graphs of these data improve the data analysis process. Schedule charts that managers can use to measure progress include Gantt and PERT charts.

The Constructive Cost Model (CoCoMo II) [Ref. 6] is one method for overall management when considering cost, schedule, and performance. CoCoMo II provides a range on its cost, effort, and schedule estimates, from best case to most likely to worst-case outcomes.

It is important to remember that software programs are notorious for going beyond schedule and over budget. Planning provides a systemic approach to controlling schedule and other program problems. A strategic plan for the system with objectives, goals, and measures becomes a strong baseline for achieving control.

	Software Metrics	Fielded System Metrics	Metrics from Cases	CAMIN Metrics
1	Cost and Schedule, Software Engineering Environment	Cost, Planning Levels	Cost, Quality	Funding Obligated and Disbursed, Schedule, Program Management, Quality Assurance
2	Computer Resource Utilization, Manpower, Effort			Critical Resource
3	Requirements Traceability and Stability, Fault Profiles	Requirements Validation	Rate in versus rate closed, Severity, Time to Close, DoD priority	Requirements, PCR, Configuration Management
4	Design Stability, Complexity, Size, Progress, Breadth and Depth of Testing		Fault testing	Development, Percent Completion, Peer Review
5	Reliability	System Readiness and Availability		User Accounts and Logins, Help, Training, User, Hardware, Software, Training, Maintenance
6		Problem Resolution		Data Interventions, Actions, Intergroup Coordination
7		System Performance	System Performance against requirements	
8		Customer Satisfaction, Expectations, Perception of PM	Customer Response and Satisfaction	

[Developed by Researcher]

Table 9. Candidate PDSS Metrics

The Software Engineering Environment (SEE) metric is a measure that is oriented toward software development, but has application for fielded software systems. This measure rates the developer's application of software engineering principles. Examples of these principles are the use of structured design techniques, the extent of tool usage, and the use of requirement management techniques. A qualified independent group should perform rating of software developers. One example of this is the SW-CMM [Ref. 20] developed by the SEI at Carnegie-Mellon University.

The results of auditing software quality assurance provide an estimation of product quality and compliance of staff to the internal processes. A review of results provides the status of action items from life-cycle reviews. Trouble reports provide insight into the quality of the product and processes, and the effectiveness of testing. Peer review results provide insight into the quality of the intermediate and final products and into the peer review and development processes. Defect prevention provides insight into the cause of defects and the effect of defect prevention activities on defect insertion rates. Quality assurance is a measure of how compliant the program staff is performing activities associated with the SEE.

2. Resource Utilization

Resources utilized for a program include computer resources, equipment, and staff. It is beneficial to maintain utilization of these resources at a constant level. Measurement of these resources over time provides indicators of fluctuation of activity and inefficient operation.

Computer resource utilization (CRU) measures performance with respect to its computer resource utilization goals and requirements. Measures of computer resource utilization provide another tool for measuring trends in costs. This measure monitors utilization of development resources.

The staff and their equipment are the critical resources of the fielded software systems. The PM can optimize costs, expenditures, and schedule through awareness and management of these resources. Measure of effort provides visibility into the contribution that staffing has on project costs, schedule adherence, and product quality. This measure helps the PM to assess current cost expenditures and anticipate future costs. This metric provides an indication of the developer's application of human resources to the development program and the ability to maintain sufficient staffing to complete the project. The manpower metric is composed of two parts: an effort measure monitors labor hours planned and expended, while a staffing measure accounts for quantity and types of personnel needed to do the work. This metric assists the Government in determining whether the developer has scheduled a sufficient number of employees to produce the product in the time and budget allotted.

3. Requirements and Configuration Management

This metric provides for the assessment of requirements traceability, validation, evaluation, tracking, and implementation. Changes to requirements are inevitable, and drive up the life cycle cost of fielded software systems. Maintaining comprehensive measures of requirements changes helps to control costs and maintain stability.

The requirements traceability metric measures the portion of the software system that has implemented the documented system requirements. Also measured, is how well the system requirements align with requirements in higher-level documents. The software system includes software code and associated items, including specifications, software design, code, and test cases. Tracking System Requirements provides an historical record.

Configuration management for fielded software systems includes submission and processing of change requests. Change requests are an important source of user requirements. Measures associated with configuration management help to assess trends in requirements and progress to accomplish these requirements. Users, funding managers, or data customers typically establish priorities and severity/importance for change requests during the CCB. When users present change requests, the response time may be important. Changes to CAMIN through Version updates can take up to two years from contract task to fielding.

4. Development and Maintenance Upgrades

The degree of difficulty of development and maintenance upgrades is dependent on the size, complexity, and stability of the software architecture and code. This metric addresses the entire process to develop and modify software, including design, code, test, and field.

Software that is more complex is harder to understand, test adequately, and maintain. Additionally, a highly complex unit has a greater tendency to contain embedded errors than a unit of lower complexity. The likelihood of introducing errors

when making code changes is higher in complex units. The design stability measure evaluates changes made to the design of the software. The complexity metric provides a means to measure and evaluate the structure of software units.

Size measures are used to estimate cost, schedule, and workload. Size of software implies the scale of the system. Measures of size include source lines of code (SLOCs), Function Points, and Feature Points. A measure of the size of a system can vary depending on method of measure. The purpose for measuring size is to define the complexity of a system and how long it takes to write or change the system. One measure is to count the number of lines of code, called "source lines of code," or SLOC. The software community accepts this method, especially for use with older programming languages. Newer programming languages, including those based on Object-Oriented logic, do not compare through lines of code. The only way to measure the size of a system for comparison purposes is to establish function point or feature point measures. Further, system size provides useful comparison only when measured consistently. It is important to be consistent in the method of counting to ensure common interpretation of the measure. The International Function Point User Group (IFPUG) [Ref. 15] has established basic counting methods to provide consistency in the methodology. However, older systems do not typically use function point analysis, so comparison is impossible. The DoD continues to require SLOC as the standard measure of system size, whereas function and feature points include complexity ratings and other factors. Measuring size of software is very controversial due to technological advances in code implementation. The basis for controversy is comparing items of like size. Systems

based on object-oriented design principles are not comparable to systems designed using functional principles. In object-oriented systems, duplication within classes means that a system may reuse lines of code. A primary feature of Object-Oriented design is to reduce complexity, maximize reuse, and minimize problems associated with future maintenance and changes.

Measuring progress is to assess the degree of certainty to complete the project on schedule. Progress is a measure of how well the project is performing with respect to its schedule. The development progress metric measures the degree of completeness of the software development effort, indicating the readiness to proceed to subsequent activities in software development. One should begin collecting data during software requirements analysis and continue throughout software development and fielded software systems.

The schedule and progress regarding work completion is a key program management tool for a software development or modification project. Developers and the PMO should negotiate the schedule to arrive at a realistic plan. For initial development and new developers, the estimate for time is usually underestimated. For developers that have specific program experience, as those on CAMIN, estimates for time and cost are very close to execution.

PMs assume program risk if the software development tasks are primarily driven by schedule. Results often include reduced quality, reduced documentation, and missed deadlines. When schedule becomes an issue for release of a software modification package for the CAMIN program, the list of tasks included in a software modification is reduced, rather than pushing the developers to meet an unrealistic schedule.

Development includes all of the iterative tasks involved in the design and writing of code. For the CAMIN program, the PM does not monitor to this level of detail. Instead, the PM monitors the processes used and certifications. The users assess the output of code during final acceptance testing before release of version update software.

The CAMIN contractor performs use cases and regression analyses to measure defect rates and correct problems. Use cases are scenarios that depict how the system is used. Ideally, there would be at least one use case for every possible use of the system, and testing would find every defect. For complex systems like CAMIN, use case analysis is very time consuming and therefore expensive.

The PM should run independent testing of the system. The tests should occur at each system modification, before the PM approves the software for release. For CAMIN, as a Management Information System with a relatively small user group, a user-based test occurs. The PMO prepares a test plan that includes evaluation of requirements from the initial tasking. The test plan includes scenarios that verify the change is in accordance with the task. Developers systematically fix and retest defects found during user testing. Occasionally, the PM and contractor may negotiate a low priority defect that would delay fielding into a later release. During testing for CAMIN modifications, the number of defects found is considered low, as it ranges from none at the least to two. Typically, user testing also yields the submission of 30-40 new change requests.

The breadth of testing, also known as "black box" testing, evaluates the testing performed on the system from the user perspective. This metric is concerned with obtaining correct outputs because of prescribed inputs. No test can cover every possible

combination of variables involved in a Management Information System. Variables include interface, platform, and use case.

The depth of testing, also known as "white box" testing, measures the amount of testing achieved on the software architecture. This metric focuses on the visibility into how the software is constructed.

5. Availability

This metric encompasses the factors that keep the system ready, operational, accessible, and user-friendly. Important components of this metric are user, system, and data administration, along with user support factors such as training and help line. The reliability metric tracks system failures caused by software and the time it takes to restore the system to its previous operating condition after these failures occur. User, system, and data administration are areas of CAMIN that the PM uses to control costs, ensure the system functions, satisfy customers, and protect system data.

The user list for CAMIN frequently changes. Usage is the basis for hardware and software purchases, and seat licenses to use software. Security advises administrators to deactivate a user account if the user is not using the system. Control of user accounts also saves administrative costs. Measures have identified CAMIN workstation users who only use capabilities that are available on the CAMIN web site. The PM revoked workstation accounts until needed. These measures also provide useful data to justify adding new thin client capability.

Training provides users with the tools and techniques for using the CAMIN system. For the complex operations in CAMIN, users need to repeat training after long periods of system disuse.

User help provides an instant tool for CAMIN users. As discussed with the case interviews in this chapter, measures of user help provide insights into problems with the system, with the user manual, and the training program.

User Hardware/Software List keeps track of the amount and types of software and hardware in the inventory. The amount of hardware and software fielded drives up maintenance costs. The amount and configuration of these products affect system functionality.

The system maintenance activities improve efficiency of system operations. For a complex system, these activities may be time-consuming. However, the actions addressed in this section are required for maintaining system operations and addressing customer issues.

6. Problem Resolution

The area of customer satisfaction is the in-depth exploration of customer problems. The goal is to create an environment where respondents feel free to report and describe, in detail, problems they have experienced. After learning about specific customer problems, it is essential to follow up and determine how well these problems were resolved.

Problem resolution is crucial to maintaining customer satisfaction. Most customers recognize that occasional problems are unavoidable and even inevitable.

However, the method and attitude that the staff uses to respond to those problems is often the difference between a satisfied and unsatisfied customer.

Good problem resolution can increase customer satisfaction beyond the level that existed before the problem occurred. Customers who report that a company has exceeded their expectations frequently cite quick, customer-oriented problem resolution as the source of their satisfaction.

7. Performance against Requirements

Measuring the performance of a system is necessary to determine customer satisfaction. Defined user requirements provide the benchmark for measuring system performance, and the requirement baseline is always in flux. System testing through IV&V and operational testing provide measures of performance. These tests must be repeated periodically to correspond to changes to the requirements, environment, or system.

8. Customer Satisfaction

Understanding customer expectations and then meeting or exceeding those expectations is fundamental to creating satisfaction. Customers become satisfied only when the system meets or exceeds expectations. It is important to recognize that expectations are not static. Performance that satisfies a customer today may not be sufficient to satisfy that same customer in tomorrow's environment. In addition, the user group is in a state of flux and users with different experiences may have different expectations.

A customer's perception of his or her interactions with the PMO is another key driver of customer satisfaction. Quite frequently, how customers feel about their treatment is more important than the underlying quality of the product or service. Poor treatment leaves a damaging and lasting impression that is difficult to overcome.

The user expects a system that meets his or her performance requirements and is easy to use. In the case of the CAMIN system, the IV&V was conducted with the intent of measuring the system against the full program requirements. To maintain configuration management, the requirements database maintains old and new system requirements. New requirements come from approved PCRs and from program management decisions. At each version release, the PM and contractor jointly conduct extensive testing on parts of the system that may have been impacted. The user, however, develops and changes expectations of a system. Most users are accessing other systems that they naturally compare. The other systems may respond more quickly, making this system seem slow. The other system may provide a simpler interface, causing users to request the same short cuts and interfaces. The users may expect to work in a familiar environment, such as Microsoft Windows or web browser. Thus, using differing computer systems, users develop expectations about speed and ease of access or operation.

	Metric	Measures
1	**Management and Planning** Cost and Schedule, Funding Obligated and Disbursed, Schedule, SEE, Planning Levels, Quality Program Management, Quality Assurance	Computed maturity level Measures quality of procedures against published procedures Quality Audits planned/conducted Nonconforming conditions found/closed/Open Monitor Strategic Plan Measure adequacy of funding Measure of costs by year, and by amount of requirement or function point Measure of funding obligations and dispersals vs. plan (Dollars spent vs. dollars allocated) Measure of hours expended vs. hours forecast and requirements Hours expended by day, month, task order/project Cost expended by month, task order/project Baseline (cost/hours/duration) vs. actual & progress (% complete)
2	**Resource Utilization** CRU, Manpower, Effort,	Percent resource capacity utilized Measure of staff levels and rate of changes by function Assess funding and personnel resources vs. work to be performed Measure of Computer Resource Utilization (CRU) vs. requirement Staffing / Equipment resources needed over lifecycle
3	**Requirements and Configuration Management** Requirements Traceability and Stability, Validation, Fault Profiles, Rate in versus rate closed, Severity, Time to Close, DoD priority Requirements, PCR	Measure of problems / defects over time and over versions Number of requirements changes Measure of priority/Measure of severity Measure of difficulty Importance of change vs. Rate Closed PCR Rate in vs. Rate Closed Requirements Identified (Percent requirements traced), fulfilled, outstanding, validated (for a release) Requirements by release, by configuration item, by category (new, baseline change, design change, implementation change) Changes per configuration item (volatility) Backup success, Backup resources used Hardware/ Software Environment Changes Number of files checked out/Number of files changed Number of users who checked out/changed a file Number of times, length of time each file was checked out Number of lines that changed per file (code only) Average number of changed lines (code only)

4	**Development and Maintenance Upgrades** Design Stability, Complexity, Size, Progress, Breadth and Depth of Testing Fault testing, Percent Completion, Peer Review	Cost to complete, Hours to complete, Milestone/event slippage Software size by version (SLOC), by tasking (function point) Periodically assess the development, documentation, peer review, and testing procedures (use SEE, where possible) Breadth, Depth of Testing, Degree of code testing Count of defects found during testing Stability and Complexity indices Percent requirements tested / passed Number and types of faults, average open age, restoration times Time to implement (baseline vs. actual) by software change/Configuration Item Defects/Problems identified, corrected, validated, time and effort to correct Peer Reviews planned/conducted
5	**Availability and Usage** Reliability, System Readiness, User Accounts and Logins, Help, Training, User, Hardware, Software, Training, Maintenance	Time system is not available for planned and unplanned outages Monitor Continuity of Operations Plan User vs. system usage, New users, and deactivated users Trainee feedback on availability, quality of training Last user training vs. error frequency for user Categorize help calls to identify trends Measure frequency of user help vs. date of last training Measure of system and document usage Count and categories of maintenance issues Count and time to resolve non-conforming conditions Mean time between failures Effort/hours expended in staff familiarization (training)
6	**Problem Resolution** Data Interventions, Actions, Intergroup Coordination	Measure actions and resolutions, time spent, type of problems Measure rate of actions vs. time to close, based on priority Problem Calls logged (by category, by users, by action) Time/effort to service calls Open problem calls Data changes/interventions logged Time/effort to make data change
7	**Performance against Requirements**	Compare system performance to requirements documents Measure system performance against defined requirements
8	**Customer Satisfaction**	Perform surveys for user satisfaction, user meetings, help line, satisfaction with program management staff, overall satisfaction

[After Table 7, Table 9, Appendix D]

Table 10. PDSS Metrics and Measures

The concepts of customer satisfaction in industry determine future customers for the product or service. In DoD, most users do not have a choice to "shop around." The NICP and Treaty community have selected CAMIN as the system that participating sites must use. Nevertheless, assessing and improving customer satisfaction is beneficial to encourage users to utilize the system and user support systems, such as the help line and manuals, and maintain timely and correct system data. The users interact with the PMO through the help line, meetings, telephone calls, and e-mails. The result is that the degree of user satisfaction determines how often the user utilizes the staff resources.

Most users present problems through the help line. The staff must then follow-up help requests to be sure that the user considers the problem closed, and is satisfied with the outcome. Data collected in the help line database can provide access to useful measures. It is also important to provide a mechanism for users to provide anonymous feedback on their perception of help provided.

9. Final Metrics List

The metrics and measures collected in this chapter provide a good baseline for analysis of systems in the PDSS phase. Table 10 provides a summary of the metrics and measures, consolidated by the eight categories that agree with Table 9. This list may prove useful in analysis of various PDSS that may be vastly different in design, application, or management.

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IV. DATA ANALYSIS OF PDSS METRICS FOR CAMIN

This chapter analyzes data collected in research for this thesis. The background presented in Chapter II contains a concise list of the CAMIN program management issues. Data from Chapter III generates a list of candidate metrics from DoD and commercial sources, and from other fielded software systems. Through analysis of these data, this chapter develops a list of the metrics that are recommended for use by the CAMIN program management.

The analysis consists of evaluating key component areas for each issue from Chapter II, and identifying the parameters that require metrics and measures. Finally, this chapter analyzes lessons learned from a review of the CAMIN program, data collection, and the case studies contained in this thesis.

A. SELECTION OF METRICS AND MEASURES FOR THE CAMIN

This section analyzes the issues to select metrics for use by the CAMIN PMO. Table 11 summarizes these metrics.

1. Funding

The issue of funding ties into all of the other program management issues addressed in this thesis. Chapter II discusses problems that arise if the program funding is less than the requirement in a given year, and over the long term. Table 11 shows the metrics and measures that serve to address the programmatic funding issues for CAMIN. Measuring success in funding includes other factors that help the PM to successfully

request and receive that funding. Following is a detailed discussion of each of these metrics, the measures, and methods of calculation.

a. Understanding Funding Needs

The PMO must evaluate each funding driver of the CAMIN program to determine if it is a valid need. The reason for this is that organizations responsible for funding the CAMIN system require revalidation of the need for requirements. All aspects of the program drive funding, so measuring all areas provides data to understand funding needs.

The methods for evaluating funding drivers include the time and cost of implementing the new requirement, which may determine the validity of a requirement. If implementation is prohibitively expensive, the alternative to use a manual or other method may be preferred. However, there are intrinsic benefits to implementing new requirements that may not lend themselves to cost-benefit analysis. The PM must consider user need, mission accomplishment, data access and protection, productivity and retention of staff and resources, and the specific needs defined by the organizations that control the funding when determining the validity of a new requirement,

Another method for evaluating funding drivers involves measuring the justification for funding needed to resolve PCRs, which comes from the CCB evaluation of change requests. The CCB evaluation measures breadth of customer need/benefit, cost and timeframe of meeting the requirement, and the direct benefit to system functionality , as well as the ability to meet the mission. The PM must retain CCB evaluation data to support future actions and to assess trends.

METRICS		MEASURES
Funding	Understanding Funding Needs	Measure each funding driver for the priority/severity of need and for the likelihood of funding acceptance
	Communication of Funding Justification	Measure the degree of understanding by the target audience
	Receipt of Required Funding	Measure and track the adequacy of funding in each area
System Availability	Power to the System	Measure the reduction in system availability due to power failures
	Connectivity	Measure the consistency and effectiveness of connectivity
	Workstation/User Accessibility	Measure the ability of users to access the CAMIN Server
	System Maintenance	Measure the frequency, nature, and impacts of maintenance activities
Data and Output Accuracy	User Competency and Preparedness	Measure PM actions that assist user competency
	CAMIN Software Design	Measure the design characteristics that cause CAMIN to meet requirements
	Data Audit	Measure the frequency and quality of audits to determine system data accuracy
	Data Interventions	Measure the frequency, nature, method and time spent on data interventions
Experienced IT Support	Leveling of Tasks	Measure the amount and types of work under the contract and the contract vehicle
	Challenges and State of the Art	Measures the trends in technology
Requirements Changes	Changes to External Environment	Measure the COTS software and hardware and the network environment to proactively adjust to changes
	Evaluation of Changes	Measure the priority, type, complexity, and severity of change requests

[Developed by Researcher]

Table 11. Selected CAMIN Metrics

For requirements based in policy, regulation, or law, and for other customer requirements the PM determines the validity based on the source. It is important to determine if the requirement is required or simply advised, and under what circumstances the requirement is valid. When a paying customer submits a requirement with funding, the PM treats this requirement as valid and relatively urgent. The PM treats requirements introduced in direct support of the system mission to be valid and evaluated based on priority.

For systematic maintenance requirements of the CAMIN system, the validation of the activities has a basis in historical data. Experience has provided a justification for the baseline maintenance activities that ensure consistent operation of the system. Experience also shows probable consequences if there is a lapse in maintenance.

Measure: Measure each funding driver for the priority/severity of need and for the likelihood of funding acceptance. Examples of funding drivers are PCRs, upgrades to hardware and software, and software/hardware maintenance costs.

Method of Calculation: Collect input from individuals that can adequately represent the user community and the mission requirements to evaluate the need. Measure the need on a predetermined scale (e.g. 1 to 10), to establish a baseline measurement. Evaluate the time and cost of implementing the new requirement. For the CAMIN program, the requirement baseline exists in terms of function point estimates. The combination of these measures provides the data needed to adequately validate the need. Knowing the cost, the need, and the benefit to the mission is sufficient to come to a business decision, based on the resources available. For example, the software/hardware

maintenance costs typically have a very high need value (10). If allowed to lapse for an amount of time, the cost would go back up to the initial purchase price. The benefit to the mission is assessed based on the potential situation if the need were not met. Without maintenance agreements, the program experiences high risk of not functioning, thus becoming incompatible with the external environment. The cost is estimated based on the purchase price from the provider and the costs incurred by the contractor in the process.

b. Communication of Funding Justification

Another key element is to assess how effectively the PMO communicates its justification of the funding needs to fund managers. This research identified no standard metric for communicating funding needs for software or for hardware. Therefore, the methods of measure suggested here are new, and require evaluation. Measures of communication effectiveness should address communicating the right ideas about the funding requirements to the right people.

Measurement in this area requires tools to assess how well the fund managers understand the funding intent and associated issues. The funding allocated may not be a useful measure of this, because other issues arise, such as availability of funding or emergency programs, which take precedence over the need for CAMIN. Nevertheless, a measure of funding requested vs. funding received provides a basis for the PM to study allocation of priorities and availability of funding.

A valid measure may be available through direct feedback. The PM should continue to talk to fund managers throughout the funding process, and make

appropriate changes to the communication process, based on feedback received. Documentation of the communication process can aid in future communication of funding needs.

Measure: Measure the degree of understanding by the target audience.

Method of Calculation: Collect data from fund managers and peers on funding rates. Correlate the amount of funding requested to amount allocated. Evaluate data against other programs in the same funding pool. If the program fares unfavorably, pursue action to improve communication. Solicit periodic feedback from fund managers to assess their understanding of program funding requirements. Institute continuous improvement to mitigate problems when identified.

c. Receipt of Required Funding

Managing the program requires sufficient funding to accomplish the activities required in support of the program. The program budget provides documentation of the funding requirements. In addition, the PM has flexibility to reallocate funding within the program dollars to compensate for funding shortfalls. However, the PM must periodically assess the adequacy of the funding in each area to use in planning for future years. One of the primary problems with reduced funding in a given year is that higher funding is required in the following year, to compensate. The next year, delayed maintenance causes higher maintenance costs, and changes to requirements become greater in magnitude, and therefore more expensive. Documenting the levels of funding, and the effects of shortfalls on the requirements provides a record

that supports future funding needs. The documentation also creates a history to justify limitations in meeting system requirements.

Measure: Measure and track the adequacy of funding in each area.

Method of Calculation: Collect data on each new requirement and the extent of funding needed to meet that requirement. Note requirements not met for that year, and the effect on the current year. Include an assessment of the impact to the program in future years. In addition, document the higher maintenance cost each year, and jumps in technology caused by short funding in prior years.

2. System Availability

System availability is one of the fundamental system requirements. Lapses in system availability over the fielded lifetime of the system highlight the need for measures in this area. System availability encompasses user access to the system or data when needed.

a. Power to the System

As discussed in Chapter II, the constant supply of power to the server is not reliable. The CAMIN server is dependent on the infrastructure within the installation for its power. The mission requirement for system availability on a 24-7 basis is above the availability requirement for other computer systems on the installation. The onus is, therefore, on the PM for CAMIN to take the necessary action to meet its unique power requirements.

Before taking action to prevent a power problem, the PM must collect data to determine the most cost-effective solution. One area to measure is the extent and

nature of power problems. The PM needs to measure the occurrence of power outages, the cause of those outages, and the frequency and duration. As the PM takes action to eliminate or mitigate power issues, documenting the trends is useful in justifying the actions taken.

Another area to measure is the effectiveness of power protection systems that are currently in place. The systems to be tested include uninterruptible power supplies, the hot backup system associated with the high availability server, and the power backups used on the installation. The data collected from this analysis provides additional justification for enhancing the systems, if necessary.

Another contributing factor to the importance of power interruptions, as a valid measurement tool, are impacts to the user community. For each power outage, users should be queried to determine the mission delay or failure during that period. Then, measure system usage rates over time to determine potential deleterious impacts from a theoretical power outage.

Measure: Measure the reduction in system availability due to power failures.

Method of Calculation: Keep track of the cause, the frequency, and duration of power outages. These data are available from the installation Department of Public Works. Query users about specific impacts to mission caused by power outages. Measure system usage over time through reports from the server.

b. Connectivity

Connectivity problems can reduce user access to the system and data, as well. The PM is often unaware of connectivity issues until users identify problems because of inability to reach the CAMIN server. This forces the PM into a reactive rather than proactive mode. Maintaining connectivity may require maintenance modification of the system to remain compatible with the environment and network systems. Measures of connectivity involve three primary issues: 1) network, 2) firewall, and 3) security.

The network is not available for significant periods due to local router problems, virus protective actions, and other reasons. Network connectivity is not critical to system operation, because the CAMIN system allows connectivity through either network or phone connection. However, the phone connection is relatively slow, compared to the network, inconveniencing users and delaying schedules. In addition, there are local policies that prevent phone connectivity via modem, and connection to the local network on the same workstation. The PM needs to track losses of network availability, and the causes, to identify systemic problems. The data is available through the local network administrator.

The increased use of firewalls creates frequent connectivity problems. One or more firewalls exist at almost every CAMIN location, and each firewall configuration must allow CAMIN client-server communication. Network administrators frequently change firewall settings. A phone connection between client and server permits bypass of the firewall, if allowed. The PMO must remain in contact with local network administrators to track firewall configurations to assist when changes occur.

The firewall is only one of many security precautions that impede connectivity. Security is of primary concern to network administrators today. Other security precautions that impede connectivity include preventing ping and blocking access to specific user segments. The primary organization within the Army that manages these security issues within the military network is the Theater Network Operations and Security Center (http://www.conus-tnosc.army.mil/), a part of the United States Army Signal Command that is located at Ft. Huachuca, Arizona. The PM must collect and track information on current security activities to assure constant connectivity between workstations and the CAMIN server. For all of these connectivity issues, the primary goal of measurement is to be prepared to proactively manage problems.

Measure: Measure the consistency and effectiveness of connectivity.

Method of Calculation: Examples of the measures for this aspect include monitoring and collecting data on firewalls, networks, and security changes. The PM should assess trends to identify changes before they occur. Data sources include all local network administrators and the U.S. Army Theater Network Operations and Security Center. Data output should be stored in a central database to identify trends.

c. *Workstation/User Accessibility*

CAMIN functionality is dependent on the ability of remote users to access the CAMIN server via the workstation. The previous section addresses network issues. Other issues that provide system access are proper configuration of the workstation and correct user permissions.

As Chapter II discusses, the workstation configuration is vital to CAMIN Client-Server functionality. Workstation configuration is difficult to assess and control at remote workstation sites. Published policies are limited in effectively managing the situation. However, the PM needs a method to assure that the workstation that is connecting to the CAMIN server is the correct configuration. The method currently used to meet this requirement addresses three aspects of workstation configuration.

First, the PMO purchases, configures, and delivers the CAMIN workstations to user locations. This action provides initial control of configuration, but has limited use in guaranteeing future control. There is nothing to prevent users from loading all CAMIN custom and COTS software onto a different workstation.

Secondly, the PMO must guarantee that only PM-procured workstations connect to CAMIN. Version 8.0 of CAMIN software prevents connection to the server unless the identifying number of the workstation network card resides in the database. This action has been effective in maintaining control of workstations.

Finally, the PM requires a method of obtaining data from remote workstations to assure compliance. The PM is currently implementing a system to collect workstation configuration data at remote sites. This new system provides users and workstation administrators with the capability to run a program, with output containing all required workstation parameters. The PMO can then request that the remote location run the program at selected intervals, and transmit the output data to the PMO for collection and analysis.

In addition, accessibility issue is user permissions. Users need to have all permissions that are required to perform needed work. CAMIN permissions restrict or permit access, by organization, by installation and facility, by application, and by action. The user administrator, currently residing in the PMO, sets these permissions. However, the need for specific permissions changes over time. The measure of permission against usage is key to establishing the correctness of these permissions on an ongoing basis. These data are available from the CAMIN server, and should be measured and evaluated for reallocation of permissions, quarterly.

Measure: Measure the ability of users to access the CAMIN Server.

Method of Calculation: The PM needs to collect and evaluate data on the configuration of CAMIN workstations to identify trends. The PM is currently developing a system to obtain these data. Where incompatibilities with the standard exist, the PM must enforce correction. The PM also needs to evaluate user permissions against needs and compare those permissions to actual system usage. This data is available on the CAMIN server. If users are found to have too many or too few permissions, the PM must take corrective action.

d. System Maintenance

System maintenance employs preventative actions to keep the system operational. Measuring system maintenance involves measuring the frequency, nature, and impacts of maintenance activities, and measuring the effectiveness of these activities (i.e. how often the system in unavailable due to lack of maintenance). Both sets of data are needed to conduct a complete trend analysis.

System maintenance activities include daily System Administration activities and implementation of system (software, hardware, and other equipment) upgrades. These actions must occur in a responsible manner, ensuring minimal impact to the user, while maintaining consistent system operations.

Daily System Administration activities include management of file sizes, creating system and data backups, managing accounts and passwords, and performing periodic system testing to identify and correct problems. A daily log maintains documentation of these activities to ensure compliance and identify trends.

Implementation of system upgrades can involve taking the system down for an extended period of up to a week. It is important to thoroughly test an upgrade before implementing it in a live user environment. The preliminary testing can anticipate most problems to precipitate preventative action, but unforeseen problems sometimes occur once the upgrade is in an operational environment.

Taking the system down requires scheduling and coordination with system users and other customers. The PMO must build in flexibility to the schedule in case a short-notice treaty inspection occurs during planned down time.

Measure: Measure the frequency, nature, and impacts of maintenance activities.

Method of Calculation: The PM should measure all aspects of proactive and reactive maintenance activities to determine trends. The individuals that perform maintenance must log actions into a central database, and take corrective action if maintenance is not in accordance with prescribed levels. The PM should also track

events when the system in unavailable due to a lack of maintenance. The event-related data should include the frequency, duration, cause, and impact of the lapse. This data is available from system logs located on the central server. In cases where the system is unavailable, the PM should take corrective action. Systemic causes of failure warrant further action that may require changing the program strategy.

3. Data and Output Accuracy

As discussed in Chapter II, data and output accuracy are critical to the success of the CAMIN system. In order to achieve data and output accuracy, users must possess skill and knowledge when executing data input and output choices. The PM provides tools to prepare users and protect data. The measures assess the effectiveness of the tools.

a. User Competency and Preparedness

Measuring user competence is a political issue, tied to employee performance ratings and user support of the system. Direct assessment of user competence creates distrust and contention. As stated in Chapter II, CAMIN system users are sometimes not computer literate, and CAMIN data processing is often an extra duty included in a workday of disparate activities. The CAMIN PM has no direct control over the CAMIN users and their performance ratings. To gain user satisfaction and timely system use, the PM provides a service that the user can trust. The PM must balance the need for improved competency against the need for timely data inputs.

Measures of user competency may include testing of users and/or punishment for user errors. However, the impracticality of using these direct measures

stems from the ability to enforce these measures, and from the resulting customer perceptions, should these measures be implemented.

In addition, measures are not practical in all cases, as system users range from those that perform a wide range of user activities to those who only perform one or two basic actions. The test would have to be adapted for each user, eliminating the perceived "fairness" of equality of the measure. In other cases, testing may not be a good indicator for infrequent users. In the case of infrequent use, a call to the help line is the preferable way to provide instructions that link users back to their initial training.

From the PM perspective, enforcement of a competency requirement means that those users that do not pass testing are removed from the user group. This action would be in direct conflict with the need for timely data input into the CAMIN system. Each site is short of staff, and there are CAMIN sites have no users that could pass the rigorous testing.

Measuring and judging users has a significant impact on customer perceptions and associated trust. There is a concern that users, concerned for their job security, may hide data errors they created in the system to prevent punitive action. Another concern is that, rather than make a mistake, the user may do nothing, resulting in system data that becomes grossly out of date. The PM needs to maintain a relationship of trust with the users, and this type of judgment, on the part of the PM, creates divisiveness and contention.

Rather than measuring and enforcing strict guidelines for user competence, the PM offers a selection of tools that the user can employ to improve

competency. These tools include training, access to help line support, and user manuals. Measuring the use of these tools does not measure user competence. However, measuring the frequency of use and the perceived benefits of use provides a measure of the tool and its utility to improve user competency and preparedness.

Training for CAMIN users enhances data and output accuracy. Training provides instructions on system use, to include how to use the workstation, how to use applications, and the significance of data. Training also provides tips and exercises to improve the quality of learning. Users require retraining when the application changes significantly and when use of the system has lapsed for only a short period, typically one month.

The help line provides special instructions and other help regarding system use and problems. The help line is a venue where users present problems about system function, use, and data. As a result, the help provided may include instructions, data intervention, and/or PCR for system modification. Also, user manuals provide systematic instructions and diagrams for system users. Data and output accuracy can improve if the manuals are easy to use, informative, and factual.

In addition to measuring the tools provided to assist users, the PM should also keep track of system users and their abilities. Consolidation of the data collected for training and through the help line, data from user interventions, and data indicating frequency and duration of use by application, provide a profile of each user over time. This profile may be useful in establishing a baseline for competency, and in measuring improvement against that baseline.

Measure: Measure PMO actions to assist user competency.

Method of Calculation: Direct measures of competence are beyond the CAMIN program control, but the PM does control the offering of materials and services to enhance user competence. A source of indirect measures is the assessment of training, the help line, and user manuals. Assessment includes how the PM provides these services, how users use the services, and the results of usage. Additionally, the PMO should count training offerings and attendance, and have instructors provide an assessment of trainee performance and improvement. If training is not resulting in user performance improvement, the PMO needs to redesign the training program. The PMO should also measure the frequency, nature, and duration of help line use. If trends indicate repeated problems, redesign of the system and/or manuals may be required. Also, assess the quality of help through trends in closeout rates and feedback from users. This user feedback can provide data to document the benefits of the manuals. The consolidation of data collected in this and other metrics provides a measure of user preparedness and an indicator of user competence.

b. CAMIN Software Design

The CAMIN software design elements should concentrate on data and output accuracy. Three considerations should be part of the software design: 1) ease of use, 2) data protections, and 3) continuous improvement. These three elements provide focus on the mission of the system to maintain accurate data, in contrast to a typical focus that supports the continuation of the existing design.

If the system is easy to use, users are more likely to use the system, and find it easier to use the system correctly. With a user base that includes infrequent users, a process-based system provides the benefit of reduced training requirements and more accurate system data. The potential downsides of process-based applications are reduced flexibility for more advanced users, and more time required to perform a given operation, (since users must go through a selection of all possible operations in the process of identifying the chosen one). Nevertheless, with data accuracy as a primary goal, the process-based approach to achieve ease of use is the preferred alternative. This process-based design change would take place over an extended period, through a long-term plan. Feedback from users would indicate if the changes make the system easier to use. Other indicators of improvement are reductions in help line calls and in data errors.

Another action that improves ease of use is the utilization of familiar platforms and interfaces. Users perform more comfortably when working in familiar surroundings. CAMIN currently operates on a Windows ™ NT Version 4.0 platform. When CAMIN converted from Windows ™ NT Version 3.51, an improvement in the comfort level of users and local administrators was noted. Future changes being considered for CAMIN include moving to a Windows ™ 2000 platform and/or to a web-based platform.

In addition, system data protections reduce the chance for user error. When systemic data errors are identified, an investigation of causes may indicate that the software can be redesigned to prevent the error or caution the user against making the error. If a redesign can help, the change is documented in a PCR and sent to the CCB for

disposition. Depending on the cost of the change, the assessed benefit, and the funding available, the change may be included in the next version of CAMIN software. The measure of success of the data protection action is the reduced occurrence of the identified data error.

A process of continuous improvement of the design should work toward retention and improvement of data accuracy. One area of continuous improvement that may enhance data accuracy is the leveraging of the system application over several programs. Initially, the system was designed to address chemical treaty requirements only. By incorporating the wholesale army accountability mission, the data is reassessed through regularly scheduled audits and inventories. Additions of Materiel Assessment Review Board (MARB) data storage, CWPF accountability functionality, and the like, further enhance the data accuracy. Measurement of continuous improvement is indirect, but can be accomplished through reduction of data errors after improvements are adopted.

Measure: Measure the design characteristics that cause CAMIN to meet requirements.

Method of Calculation: Measure the ease of use of the system through user feedback. The PM should use formal and informal approaches to obtain user opinions. A measure of data errors by frequency, type, cause, and severity provides benefit, because it addresses the design areas. However, this measure requires high quality data audits, which are outside PM control.

c. Data Audit

The data audit is the most systematic method available for assessing the accuracy of CAMIN data. Data audits must support each type of data within CAMIN, with representation from the pertinent mission areas. However, there are few formal procedures in place for audit of CAMIN data. Table 12 describes the organizations responsible for audit of identified CAMIN data.

The key organizations involved in data are the NICP, the MARB, the treaty organization, the quality and maintenance staff within SMT, and local property accountability organizations. The NICP audits CW storage and destruction at the end of each destruction campaign. The NICP also requires the local custodial officer at the site to perform an annual inventory of all CW storage locations, reconciled against CAMIN data.

When the site receives notification of a short-notice treaty inspection, the local treaty compliance officer may conduct an emergency data review. This effort may result in surface corrections, but does not replace the detailed review required to assure data is correct. During the treaty inspections, the international inspection team conducts a more comprehensive audit of CAMIN treaty data. However, inspections are undesirable times to discover data errors, requiring explanations and negotiations, and breeding distrust.

DATA CATEGORY	ORGANIZATION	DATA AREAS
CW	NICP	Storage, Movement, and Destruction, Ownership Codes
	MARB	MARB data
	Treaty	Storage, Movement, and Destruction
	Quality and Maintenance	Defect Codes, Condition Codes
	Local Property Accountability	Storage, Movement, and Destruction, Hazardous Waste Info,
Former CWPF	Treaty	Storage and Destruction
	Local Property Accountability	Storage and Destruction
Schedule 1	Treaty	Storage, Movement, and Consumption
	Local Property Accountability	Storage, Movement, and Consumption
Site Information	Treaty	Site Diagrams, Process Flow Diagrams, Installation and Facility Info
	NICP	Installation and Facility Info
	Quality and Maintenance	Planographs, Grid Definitions, Installation and Facility Info
	Local Property Accountability	Site Diagrams, Planographs, Process Flow Diagrams, Installation and Facility Info

[Developed by Researcher]

Table 12. CAMIN Data Audit Responsibilities

None of the other audits listed in Table 12 take place on a systematic basis. This is a matter of concern in support of CAMIN data accuracy and associated measures. The PMO does not have sufficient staff to conduct these necessary audits, and the organizations with cognizance over the current data are better qualified to conduct the audits.

Data managers need to periodically audit the CAMIN database for accuracy. These audits help to identify unique systemic data problems. The data managers need to have an understanding of the data and output requirements. The CAMIN program needs data managers from both the Treaty and the wholesale accountability functions to work together in the interest of maintaining consistent data. Evaluation of data errors can help to determine if a design change can prevent future errors. Audit of data also provides a method for measuring the quality of system, training, and other user help systems.

Measure: Measure the frequency and quality of audits to determine data accuracy.

Method of Calculation: The PM should measure the frequency and output of audits, collecting data containing users, auditors, locations, and expected results. These data are available through queries of the organizations that should be conducting the audits. The PM does not have control over the audit process, but may provide feedback of this measure through the chain of command.

d. Data Interventions

Through data interventions, the Data Administrator corrects user errors, intercedes to bypass software design, and performs mass changes to system data. The actions are performed through manipulation of the data in the CAMIN database. Data interventions can be time consuming and add risk to data accuracy. The action does not leave an audit trail, so documentation of the intervention is important. The process for a data intervention includes design of the intervention, testing the intervention in the

training database, and implementation and notification of the users involved. A Data Administrator on the contractor staff performs all data interventions. The Data Administrator only performs data intervention with authorization of the PMO.

It is inevitable that humans make errors. For many important data transactions, the CAMIN system requires that a second CAMIN user confirm the accuracy of the transaction through the QA process. However, data errors continue to occur, even with QA. Before automation, when users made errors, they simply marked up the paper document. In the TCM, the system that immediately preceded CAMIN, users could enter the database and correct the basic data. Many errors in the database were perpetuated through these "back door" approaches, and CAMIN does not permit users to access or manipulate the CAMIN database. These data interventions for error correction improve the accuracy of data. Consequently, the software design has controls to prevent users from violating laws, regulations, or treaty, and to protect the CAMIN data. In rare cases, there are exceptions to these rules, and the Data Administrator must intercede to bypass the software design.

Infrequently, a change to policy, laws, regulations, or treaty requires a systemic modification to the CAMIN data. For these systemic data changes, the PM must determine if it is advantageous to the program for the Data Administrator to perform a mass change to the database, or if users must perform all transactions individually. Mass changes can improve system data through consistency of data input and through customer satisfaction.

Measure: Measure the frequency, nature, method, and time spent on data interventions.

Method of Calculation: In all of these cases, the Data Administrator should document the process for each intervention so that it can be repeated. The Data Administrator should also record the frequency, nature, method, and time spent on data interventions. The PM can use the data to identify trends that may justify changes to the system design.

4. Experienced IT Support

The need for experienced IT support is fundamental to a successful program. Experience is important for two reasons: 1) The learning curves are very long for IT systems, and 2) Retention is difficult for IT professionals in the current economic environment, where demand for technical ability is high. The high performers assure career success by demanding high salaries and maintaining leading edge skills.

This issue applies to both the Government and contractor staffs. Government personnel and salary systems provide challenges in hiring and maintaining these IT professionals. One reason is that the Government contracting system is oriented toward competition and controlling salary rates. As a result, the PM for CAMIN has no IT professionals on its staff. This creates a greater dependency on contractor IT experience to maintain the system. Introducing a competitive contract under the current situation would be extremely risky to the program. This also creates difficulty in the period between contracts, with no Government staff to provide continuity for maintenance.

a. Leveling of Tasks

The IT tasks for the CAMIN system consist of system administration, data administration, design, development, and test. This varied combination of IT work requires knowledge, skills, and abilities that rarely exist in a single person. Programs invest time and dollars in training and providing experience to a group of IT professionals. The program must have the funding and workload to support the retention of the group to perform the IT functions over a length of time that is sufficient to gain benefit from the investment. The minimum retention goal is three years. A reasonably constant amount of work in each of these areas supports the retention of the skilled key IT personnel. Level funding is one key element in maintaining constant workload. Another element that can assist from a contract perspective is the type of contract.

Level funding can occur through effective budgeting and responsible management. The type of contract and method of administration can improve the PM's ability to retain an experienced IT support staff. The contract type should provide consistent and adequate funding, and work levels. Multiyear contracting can be helpful in leveling the tasks. The PM needs to periodically assess funding and contracting issues to determine the adequacy in maintaining a stable IT workforce. This data is available within the PMO and through contractor reports.

The IT Fund, defined in U.S. Code, Title 40, Section 757, (Ref. 21) provides valuable tools in addressing these IT issues for the contract. The Government Services Administration has authority to award and administer IT multi-agency contracts and to fund contracts on a reimbursable basis through a separate IT fund. GSA is the

only Executive Agent of that fund, designated by OMB under the Clinger Cohen Act (Ref. 5). In order to promote the efficient management, coordination, operation, and utilization of resources; the fund has been established without fiscal year limitation, and allows for the use of multi-year contracts for IT hardware, software, and services. This multiyear contracting authority can be used when the following criteria are met: funds are available and adequate, the contract is fully competitive, the need continues for the contract period, it yields substantial cost savings, and it cannot exclude small businesses. The IT Fund provides very valuable tools, which can be used when contracting through GSA.

Measure: Measure the amount and types of work under the contract and the contract vehicle.

Method of Calculation: Periodically assess if funding and contracting are adequate to maintain a stable IT workforce. This data is available within the PMO and through contractor reports. If work is inadequate, the PM should provide data to decision makers to help make informed decisions about the program and funding.

b. Challenges and State of the Art

There are many good reasons for a program to keep up with state of the art technology, and maintaining experienced IT professionals on staff may be the least important of those reasons. However, keeping a challenging, "state of the art" program provides the program developers and other IT professions with another reason to remain on the program, as it provides a continuous learning environment. The technology on the

program should not stagnate to the point where schools and the rest of the IT world no longer use that technology.

Measure: Measure the trends in technology.

Method of Calculation: Assess the CAMIN system based on these trends. Obtain information on technology trends through trade journals, conferences, and contacts. Establish program strategies based on sound business practices, using these trends to support decisions.

5. Requirements Changes

Changes to system requirements are perpetual through the life of the system. The changes provide the continuation of system functionality in a changing environment. Frequency of changes drives the pace of the system and funding requirements.

a. Changes to External Environment

Changes to COTS software and hardware that are part of the CAMIN system drive changes to CAMIN. The reasons to adopt these COTS-driven requirements changes, include maintenance support availability and functionality within the external policies and environment. These factors are out of the control of the PM. The cost effectiveness of COTS is realized in the avoidance of development costs and the avoidance of maintenance personnel. Despite these factors, the Government and commercial industry have accepted this trade-off, and use COTS as much as possible, as general policy.

However, maintenance support is only available as long as the COTS developer chooses to support it. The IT industry is so volatile that support to a legacy

system often stops after about a year of fielding a newer version of that system. The CAMIN has flexibility even after software support has stopped. The COTS software will function as long as the interfaces still work, but may fail to comply with new policies. Once support stops on COTS hardware, the manufacturer does not offer maintenance contracts and replacements parts become difficult to find.

As a result, the CAMIN PMO must try to remain compliant with the frequently changing external environment and policies. Recent changes that fall under this category are networks and firewalls, Y2K compliance, and handicapped accessibility to web sites. These policy changes are often unpredictable, implemented on short notice, and imposed with no associated funding. The common link is that these external changes are beyond the control of the PM, and yet the PM must adapt to them. Program planning and funding must allow for these kinds of changes. The PMO must maintain awareness of environmental changes from COTS developers, and from Federal and industry policy organizations.

Measure: Measure the COTS software, hardware, and the network environment to proactively adjust to changes.

Method of Calculation: Track the history of changes to predict future needs. The PM can obtain information through Federal and trade journals, industry conferences, and contacts. Establish program strategies based on sound business practices, using these data to support decisions.

b. Evaluation of Changes

The evaluation of changes to the CAMIN system takes place during CCB meetings. Voting membership in the meetings includes user representatives, funding representatives, and mission representatives. Consideration of priority, complexity and severity, and costs helps the CCB and PM make appropriate decisions, given resource limitations. As indicated, one consideration in evaluating changes is priority. Priorities are pivotal to decisions making, and often determining if the change is important enough to pursue. A determination of the type of change (defect, problem, or enhancement) also has influence on priority designation. The designations of priority and type are set by the user community and by the funding organizations, with input from the contractor.

Fielding of changes to software can occur either through a full version release or through a patch. The contractor evaluates each change to determine its suitability to be included in a patch. In addition, the size of the change determines whether to field the change through the NIPRNET or a compact disk.

Another factor in the decision is the complexity and severity of changes. The contractor determines the complexity through function point analysis, and provides the data to the CCB. Managers may decide to postpone changes that consume large amounts of time and other resources, in order to accomplish actions that are more pressing. The cost factor for each PCR is significant, and is determined from the function point analysis, and the consumption of resources may make them prohibitively costly and time consuming to implement.

For implementation, the CCB collects all of these data to use in determining the disposition of change requests. The CCB analysis results in an action for each PCR that either approves, disapproves, leaves in an "under consideration" category, withdraws, or designates as overtaken by events. When funding becomes available, the PM considers approved and urgent actions in generating a contract modification to implement a version upgrade to the CAMIN software.

Measure: Measure the priority, type, complexity, and severity of change requests.

Method of Calculation: For each PCR, determine priority, type of change, suitability of the change to be fielded in a patch, complexity and severity, and cost. Data comes from the contractor, from CCB members, and from the submitter of the PCR. Data is stored in central database and used in tracking requirements and making upgrade decisions.

B. LESSONS LEARNED

The analysis from this thesis results in lessons that can provide benefit to the CAMIN PM. The lessons may also apply to other fielded software systems and IT systems managers, as well. These lessons learned are identified in the following paragraphs.

Ensure that decision makers fully understand the CAMIN program requirements (software, hardware, people, dollars).

Decision makers must have the salient facts before making informed decisions about the program. Those making decisions about software, hardware, people, and dollars may not realize the significant differences between IT/ fielded software systems and other programs. For example, decision makers need to understand that updates of software are more frequent than hardware and persist through the life of the system. Further, each individual program has unique characteristics. The PM must keep decision makers informed on program issues and changes to the program.

Ensure that users and their supervisors understand and take responsibility for having competent (trained and prepared) CAMIN system users.

Users are essential to CAMIN and its data, and the users on the CAMIN system experience unique challenges of insufficient time and technology skills. Managers do not understand what is necessary in terms of time and money to select and maintain competent system users. Beyond that, many cannot afford to expend the necessary resources on training and maintenance of users. For example, managers and users may not realize that when use of the system is infrequent, users need to spend additional time on training and practice to maintain skills.

Managers need to monitor the performance of CAMIN users under their supervision to assess the quality of performance. Insufficient audits take place at the oversight level to detect errors in data. Site responsibility for data is very important in

cases where only the site personnel know the "ground truth" about the data, and can detect data errors.

Ensure that mission representatives understand the importance of data audits.

Data audits can significantly improve the quality of data in CAMIN, and can help to monitor the skill level of system users. The lack of sufficient audits increases the program risk, by allowing existing data errors to go uncorrected. Those in a position to audit CAMIN data, as shown in Table 12, need to understand the importance of audits to the data relevant to particular programs. Performance of the data audits requires knowledgeable personnel, dedicating considerable time and effort to the action. The required frequency of data audits is variable, dependent on the volatility of data in the system.

Maintain knowledge of trends and pending actions in the external IT environment, for both Government and industry.

The environment has a significant influence on the CAMIN program and its resources. Changing client needs and changes to the external environmental drive requirements changes and subsequent system updates. External requirements for CAMIN can come from many sources, including the command CIO, AMC, Army, DoD, Congress, and the Treaty organizations. Changes come in the form of policy, regulation, or law, and are rarely accompanied with the funding required to implement.

Work toward Thin Client Architecture for CAMIN.

For systems that have remote users, Thin Client is often more practical than Client-Server. The Case Interviews revealed a consistent conclusion with the Thin Client design. For the CAMIN system, each step toward total thin client, or web-based, architecture reduces the number of CAMIN workstations the program has to procure and support. Firewall issues become minimal. Access to data is greatly improved, as users with a CAMIN password can log into CAMIN from workstations with Internet connectivity. This action is consistent with the program objective to conform to the external environment.

Achieve a constant workload for the CAMIN contractor to retain experienced IT support.

Experienced IT support helps a program to perform more efficiently. Since the CAMIN program has no IT professionals in the PMO, there is a strong dependency on the contractor to provide continuity as well as experience. Performance becomes more efficient and consistent when leaning curves and experience curves are minimized. A core of experienced personnel can provide leadership and guidance to a staff of developers working on a version upgrade or patch.

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V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Following is a brief discussion of each of the conclusions that arise from the research and analysis. The analysis of a specific program is required to determine issues and the associated required measures. For example, the research into possible metrics does not reveal measures associated with communicating program funding needs. The examination of system issues for CAMIN demonstrates the clear need for metrics in this area.

The conclusions that follow should assist in providing statistical data to support funding justification. The organizations that justify and analyze funding for CAMIN require supporting documentation for these actions, but planning what data are required or requested in the future is rarely possible. A PM benefits from developing methods of easily capturing measurements for different aspects of the program. CAMIN uses databases to track action items, CCB PCR information, requirements baseline and changes, and the like. However, additional metrics are necessary if the program is to be supportable in the long-term.

The CAMIN program requires software metrics and fielded system metrics.

The analysis shows that the CAMIN PM must use metrics from both software and from fielded systems to address primary programmatic issues. Key areas not addressed in software metrics are customer satisfaction and availability. Both of these areas are essential to evaluation and justification of fielded systems.

The CAMIN program requires metrics that are specific to the program, utilizing standard and non-standard metrics.

The CAMIN system needs metrics that are not standard to software or fielded systems. One example is a metric to address communication of funding requirements. The funding sources for CAMIN are inexperienced in software systems, and are unfamiliar with the iterative nature of PDSS management.

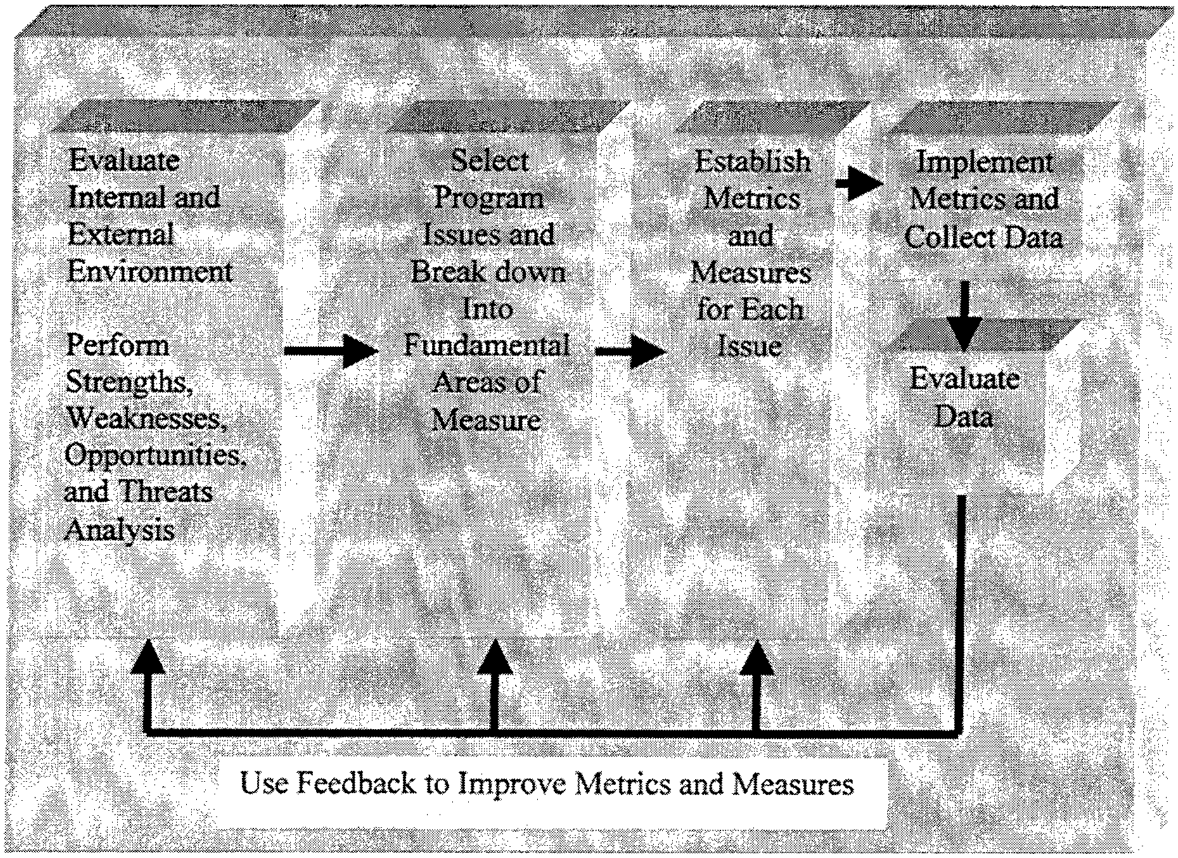
The PMO must continually evaluate metrics for the life of the system.

The program issues change through the life of a system. Political, policy and requirements changes are continuous, and drive program issues. Issue changes require a review of program metrics.

A model for establishing metrics that this thesis uses is depicted in Figure 9. The first step is to establish issues, through a thorough system analysis, including evaluation of the program's internal and external environment. The issues should also consider program strengths, weaknesses, opportunities, and threats. After issues become clear, the issues must be refined into fundamental areas of measurement. The metrics and measures of each issue must be established, along with methods for data collection and analysis. Implementation and data collection provide the data needed for evaluation. The evaluation process may yield changes to system management, operations, or measures.

These changes must be fed back into the metrics process to maintain a current system of measures. Finally, the PM must reevaluate the entire process of establishing

the program issues that drive metrics. The reevaluation should occur annually, concurrent with revision to the program strategic plan.



[Developed by Researcher]

Figure 9. Model for Selecting Program Metrics

Management Information Systems are unique.

Management Information Systems requirements change frequently, affecting overall program management and funding. These systems manage financial, office,

property, and other office-oriented missions. Drivers for the requirements changes include external environment, policy, user group, and COTS.

Each fielded software system may require unique metrics.

The metrics required for CAMIN, at this point in the life cycle, may be different from other fielded software systems. Each fielded software system PM must study program issues to develop a set of metrics for that particular program. Program managers should not rely on published standards for metrics.

B. RECOMMENDATIONS TO CAMIN PROGRAM MANAGER

The CAMIN PM should adopt the set of metrics in Table 11 for managing the CAMIN program. These metrics are the correct metrics for the system, as it exists today. The measures derived through application of these metrics should reside in a central repository where all who are involved in the program management process of CAMIN can access and use the data collected.

The PMO should reassess these metrics and data each year, using the process described in Figure 9. Reassessment should occur in consonance with the publishing of the Annual Business Plan for CAMIN. The reassessment should look at the cost of collecting the data, as a factor in assessing the value of the measure. The PM should revise the Annual Business Plan to reflect the current metrics and results to date. The PM should use the process depicted in Figure 9 in the analysis.

The lessons learned from this research, described in Chapter IV of this thesis and listed here, become additional recommendations to the PMO. The PM should strive to achieve these actions, within the control and purview of the organization.

- Ensure that decision makers fully understand the CAMIN program requirements (software, hardware, people, dollars).
- Ensure that users and their supervisors understand and take responsibility for having competent (trained and prepared) CAMIN system users.
- Ensure that mission representatives understand the importance of data audits.
- Maintain knowledge of trends and pending actions in the external IT environment, for both Government and industry.
- Work toward Thin Client Architecture for CAMIN.
- Achieve a constant workload for the CAMIN contractor to retain experienced IT support.

C. RECOMMENDATIONS TO OTHER PDSS MANAGERS

PDSS managers who are interested in defining appropriate metrics for their program should follow the same template as was used in this thesis, as shown in Figure 9. Developing a list of issue areas for the unique fielded software system is the first step in this process. For systems where issues are common to CAMIN, the analysis is complete. For different issues, a review of the candidate metrics may help to develop a tailored list of metrics for a fielded software system. During the analysis, PDSS managers should keep an open mind to new metrics that may fit their particular program and its issues.

D. FUTURE RESEARCH

This section looks at areas that warrant future research. The areas of PDSS and metrics bring a wide range of ideas for research, encompassing the metrics for CAMIN program and other programs in the PDSS phase. Additionally, there is a wide range of other research to be done in the study of managing fielded software systems. This area is becoming more important as more software systems are fielded.

1. Evaluate Outcome from Metrics Selected on CAMIN Program

An area of research that grows directly from this thesis is assessment of implementing the thesis recommendations. The analysis would contrast the value of the metrics against the imagined benefit, assess the measures against the five issue areas for the reporting period, and evaluate the cost of the implementing and using these metrics.

2. Evaluate Selected Metrics for Other PDSS Programs

Another area that relates to this thesis is to assess how another fielded software system could use the outcome of this thesis. This action would include measuring the value of the metrics against the imagined benefit. It may also compare the results identified for the other fielded software systems, and compare to the results on the CAMIN program.

3. Evaluate Other Aspects of Fielded Software Systems

Metrics is only one area of interest in the program management of fielded software systems. The issues uncovered during the course of case interviews and other

data collection require further analysis. This is a short list of ideas for future research into PDSS management.

Research into the nature and necessity of requirements changes after fielding would be beneficial. The frequent changes to requirements for fielded software drive cost and workload for the life of the system. Many of the requirements changes for CAMIN are not foreseeable, so the results of such analysis would be instructive for PMs.

The maintenance costs for PDSS seem uncommonly high to most Army managers. The annual costs run about 20 percent of the total development cost of a system. A case analysis of program management costs for PDSS Management Information Systems across Army or DoD would provide useful baseline data and analysis.

Another area of research evaluates trends in system architecture and management that can improve system access, ease of use, and avoid cost through the system life cycle. As with hardware systems, the initial design for software systems can drive up costs in maintenance and in logistics support. The DoD approach is to maximize use of COTS and standard programming languages. This research may support the value of the recommendations.

Case research into PDSS to compare management techniques may provide insight into successful and unsuccessful approaches within DoD. The size, complexity, and visibility of the system play into the management techniques. For example, a system rated with a high acquisition category requires a classic PM structure within DoD, and has rigid requirements during the system development. After fielding, DoD regulations

are not as directive of system management requirements as those established for developmental systems.

Finally, the study of retention of IT professionals on a fielded software systems can provide data and analysis that would address both DoD employees and contractors. The results may contribute to hiring practices and pay scale policies within DoD, and to IT contracting practices. The practice of acquiring and retaining qualified, capable, and consistent IT professionals is the core of a successful development and sustainment program.

APPENDIX A. CORRESPONDENCE

The author requested these data from the managers of systems considered for the case interviews. The author conducted Case Interviews on phone and in person.

Full Name of System

Type of System

Mission

Scope

Size (SLOCs)

Architecture (very general)

Number and types of users and connectivity

Brief History of development and versions

Metrics and Measures, and other program management Tools

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APPENDIX B. CAMIN WORKSTATIONS AND USERS

[After Ref. 14]

LOCATION	FACILITY	FACILITY TYPE	WKSTNS USERS	WEB ONLY USERS
Aberdeen, MD	Aberdeen Chemical Demilitarization Facility (ABCDF) (Under Construction)	CW Destruction	0	0
Aberdeen, MD	Edgewood Chemical Activity (ECA) (Active Stockpile Site)	CW Storage	3	2
Aberdeen, MD	Edgewood Chemical Biological Center (Active Operations)	Schedule 1 Single Small-Scale Facility (SSSF)	2	3
Aberdeen, MD	Program Manager for Chemical Demilitarization (PMCD)	Management and Operations	2	5
Aberdeen, MD	Soldier and Biological Chemical Command (SBCCOM)	Management and Operations	4	9
Anniston, AL	Anniston Chemical Activity (ANCA) (Active Stockpile Site)	CW Storage	5	2
Anniston, AL	Anniston Chemical Demilitarization Facility (ANCDF) (Under Construction)	CW Destruction	0	2
Commerce City, CO	Rocky Mountain Arsenal (Active Destruction)	Former CWPF	2	0
Dugway, UT	Dugway Proving Ground (Active)	CW Storage	2	2
Fort Leonard Wood, MO	Fort Leonard Wood 10 kg Facility (Active Operations)	Schedule 1 10 kg Facility	1	2
Hawthorne, NV	Destruction Facility (Intermittent, --Currently Inactive)	CW Destruction	0	0
Johnston Island	Johnston Atoll Chemical Agent Destruction System (JACADS) (Active, almost complete)	CW Destruction	4	6
Lexington, KY	Blue Grass Chemical Activity (BGCA) (Active Stockpile Site)	CW Storage	4	0
Lexington, KY	Blue Grass Chemical Demilitarization Facility (BGCDF) (Planned)	CW Destruction	0	0

LOCATION	FACILITY	FACILITY TYPE	WKSTNS USERS	WEB ONLY USERS
Newport, IN	Newport Chemical Demilitarization Facility (NECDF) (Under Construction)	CW Destruction	0	1
Newport, IN	Newport Chemical Depot (NECD) (Active Stockpile Site)	CW Storage	2	4
Newport, IN	Newport Chemical Depot (NECD) (Active Destruction)	Former CWPF		
Pine Bluff, AR	Pine Bluff Chemical Activity (PBCA) (Active Stockpile Site)	CW Storage	3	8
Pine Bluff, AR	Pine Bluff Chemical Activity (PBCA) (Active Destruction)	Former CWPF		
Pine Bluff, AR	Pine Bluff Chemical Demilitarization Facility (PBCDF) (Under Construction)	CW Destruction	0	2
Pueblo, CO	Pueblo Chemical Demilitarization Facility (PUCDF) (Planned)	CW Destruction	0	0
Pueblo, CO	Pueblo Chemical Depot (PCD) (Active Stockpile Site)	CW Storage	3	3
Tooele, UT	Chemical Agent Munitions Destruction System (CAMDS) (Active)	CW Destruction	2	0
Tooele, UT	Deseret Chemical Depot (DCD) (Active Stockpile Site)	CW Storage	10	3
Tooele, UT	Tooele Chemical Demilitarization Facility (TOCDF) (Active)	CW Destruction	0	1
Umatilla, OR	Umatilla Chemical Demilitarization Facility (UMCDF) (Under Construction)	CW Destruction	0	2
Umatilla, OR	Umatilla Chemical Depot (UMCD) (Active Stockpile Site)	CW Storage	2	4
Washington, DC	Department of Army	Management Only	0	2
Washington, DC	US Army Nuclear and Chemical Agency	Management Only	0	1
Washington, DC	Defense Threat Reduction Agency	Management Only	0	3
Honolulu, HI	US Army Pacific (USARPAC)	Management Only	0	1
TOTALS			53	68

APPENDIX C. CAMIN LINES OF CODE

[From Ref. 4]

	Version 8 Components	Version 8	Version 7.5	Version 7
NT Applications	Ad Hoc	774	757	757
	Alert Catalog	1459	1469	1469
	Annual Inventory	12501	11952	11952
	CAMIN DLL	93074	87361	81243
	CAMIN Settings	1794	1860	1754
	CAMIN Setup	2548	2641	2437
	Compare	6063	6162	6162
	CW Destruction Reporting	0	9352	9352
	CW Destruction Scheduling	0	11731	11731
	CW Items	9650	9564	9562
	CWPF History	20329	13252	13354
	CWPF Scheduling	23348	24326	23221
	Data Administration	565	0	0
	Declaration Catalog	3265	3250	3238
	Declared Chemical	6338	6459	6397
	Declarations	10946	11371	11343
	Data Download	2667	2683	2683
	Material Release	12402	9324	9321
	Notification Catalog	2700	2742	2759
	Notifications	9274	9965	9904
	Notify Server	2477	2491	2134
	RAS Manager	3086	4445	4687
	Reports	2487	1997	1934
	Schedule 1	29667	25921	27873
	Schedule 2, 3, Other	22122	22345	22321
	Site Diagrams	7952	0	0
	Site Information	16458	21111	21073
	Stock Records	59516	36435	37437
	User Administration	9141	9903	10318
	NT Total	**372603**	**350869**	**346416**

Server Applications	Version 8 Components	Version 8	Version 7.5	Version 7
	Chlst	582	528	473
	chlst_lib	19888	19776	9110
	combine	11546	8437	5036
	compress_lib	4675	4695	4671
	dbupdate	450	439	390
	Dcelib	4489	4487	4492
	decl_lib	10419	9813	7787
	decl_rpts/decl_cw_dest	23462	23458	21242
	decl_rpts/decl_cw_initial	19091	19091	12851
	decl_rpts/decl_cw_sched1	0	7752	13635
	decl_rpts/decl_cw_sched2_3_doc	52036	52034	21657
	decl_rpts/decl_cwpf_ann_dest_rpt	5224	5220	3333
	decl_rpts/decl_cwpf_ann_dest_sched	16495	16483	10688
	decl_rpts/decl_cwpf_initial	17004	17002	18812
	decl_rpts/decl_view_comments	1162	1162	592
	delete_elements	3666	3212	1723
	dispatcher	4122	3615	3111
	external_trans	0	0	2605
	file_server	2090	1911	1825
	fwd_n_reject_docs	9693	10733	5512
	ing_lib	2090	2090	2714
	internal_trans	0	0	3156
	issue-docs	1470	1405	905
	Lib	2066	2048	1922
	local_data	137	137	135
	planagraph	7637	5220	3418
	post_docs	55948	35629	21225
	q_combine_msg	133	133	130
	qa_process	10447	4997	3254
	Server_lib	1822	1606	1448
	sql_batch	37613	40582	12870
	stock_trans	320	143	0
	slashgo	76	76	76
	activate_user	141	141	142
	add_dce_users	272	272	267
	add_server_users	324	324	354

	Version 8 Components	Version 8	Version 7.5	Version 7
Server Applications	camin_archive	57	57	57
	camin-files-clean	4063	4555	0
	camin_shutdown	57	57	57
	camin_test	294	294	0
	check_backup	374	374	0
	check_backup_fs	386	772	0
	clr_rtn	107	107	107
	dcewho	262	262	262
	del_dce_users	105	94	95
	dirlist	0	0	0
	filetime	52	52	0
	list_dce_users	233	233	233
	mailbox_test	169	174	0
	procinfo	225	225	0
	sho_db_users	140	140	141
	sho_queues	46	46	46
	include	8202	7669	10358
	HA probes	3100		
	Server Total	**344462**	**319762**	**212917**

	Version 8 Components	Version 8	Version 7.5	Version 7
Web Applications	CAMIN Help	9641		
	HTML	5662	632	0
	Servlets	17339	13243	0
	Applets	54172	43435	0
	Web Total	**77173**	**57310**	**0**

	Version 8 Components	Version 8	Version 7.5	Version 7
Report Templates	CW Inventory Reports	9800	4500	4300
	CWPF Reports	2300	1900	1900
	Weapons & Agent Reports	1100	900	900
	Installation Reports	700	700	700
	Permission Reports	800	600	600
	Request Reports	200	200	200
	Schedule 1 Reports	1100	1100	1100
	Oracle Reports	11000	2100	0
	Reports Total	**27000**	**12000**	**9700**

	Version 8 Components	Version 8	Version 7.5	Version 7
Database Structure	Tables	3410	2674	2561
	Views	3294	2010	2010
	indexes	620	510	823
	grants	422	335	335
	synonyms	422	328	0
	Backup scripts	2113		
	Database Total	**10281**	**5857**	**5729**

System Totals	**831519**	**745798**	**574762**

APPENDIX D. CAMIN CONTRACTOR METRICS

[From Ref. 3]

Requirements	❖ Requirements Identified ❖ Requirements fulfilled ❖ Requirements outstanding ❖ Requirements validated (for a release) ❖ Requirements by release ❖ Requirements by Configuration Item ❖ Requirements by category (new, baseline change, design change, implementation change) ❖ Changes per configuration item (volatility)
Program Management	❖ Cost to complete ❖ Hours expended by day, month, task order/project ❖ Hours to complete ❖ Cost expended by month, task order/project ❖ Baseline (cost/hours/duration) vs. actual & progress (% complete) ❖ Software size by version (SLOC) ❖ Software size by tasking (function point)
Quality Assurance	❖ Quality Audits planned/conducted ❖ Nonconforming conditions found ❖ Nonconforming conditions closed ❖ Open nonconforming conditions.
Configuration Management	❖ Backup success ❖ Backup resources used ❖ Hardware Environment Changes ❖ Software Environment Changes ❖ Number of files checked out ❖ Number of files changed ❖ Number of users who changed a file ❖ Number of files changed ❖ Number of times each file was checked out ❖ Number of users who checked out a file ❖ Number of users who changed a file ❖ Number of lines that changed per file (code only) ❖ Average number of changed lines (code only) ❖ Average length of time a file was checked out
Training	❖ Training Requirements, vs. training fulfilled ❖ Effort/hours expended in staff familiarization (training)

Peer Review	❖ Peer Reviews planned/conducted ❖ Problems/Defects identified ❖ Problems/Defects closed ❖ Time to Closure
Critical Resource	❖ Staffing Needed by Lifecycle ❖ Equipment resources needed by Lifecycle
Maintenance	❖ Problem Calls logged (by category, by users, by action) ❖ Time/effort to service calls ❖ Open problem calls ❖ Data changes/interventions logged ❖ Time/effort to make data change
Development	❖ Time to implement (baseline vs. actual) by software change/Configuration Item ❖ Defects/Problems identified ❖ Defects/Problems corrected ❖ Defects/Problems validated ❖ Time to closure (date corrected -date identified) ❖ Effort to correct
Intergroup Coordination	❖ Action Items logged ❖ Action Items open ❖ Time to close items

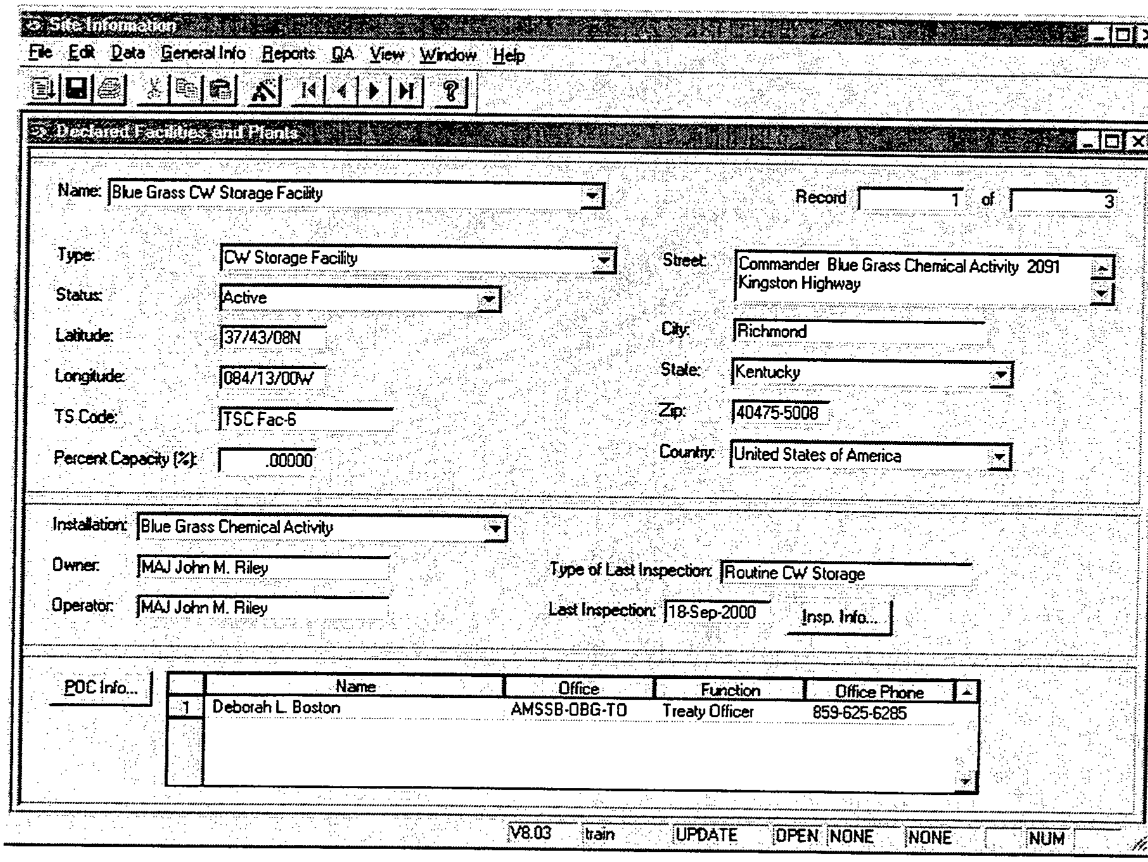
APPENDIX E. CAMIN SCREEN CAPTURES

This appendix shows samples of screen captures from the CAMIN system. The data displayed in these screens is from the "training" database, and are likely to be invented data. This rudimentary hierarchy of the CAMIN interface helps explain how the following screens fit into the larger CAMIN system.

CAMIN Applications	CAMIN Web Site

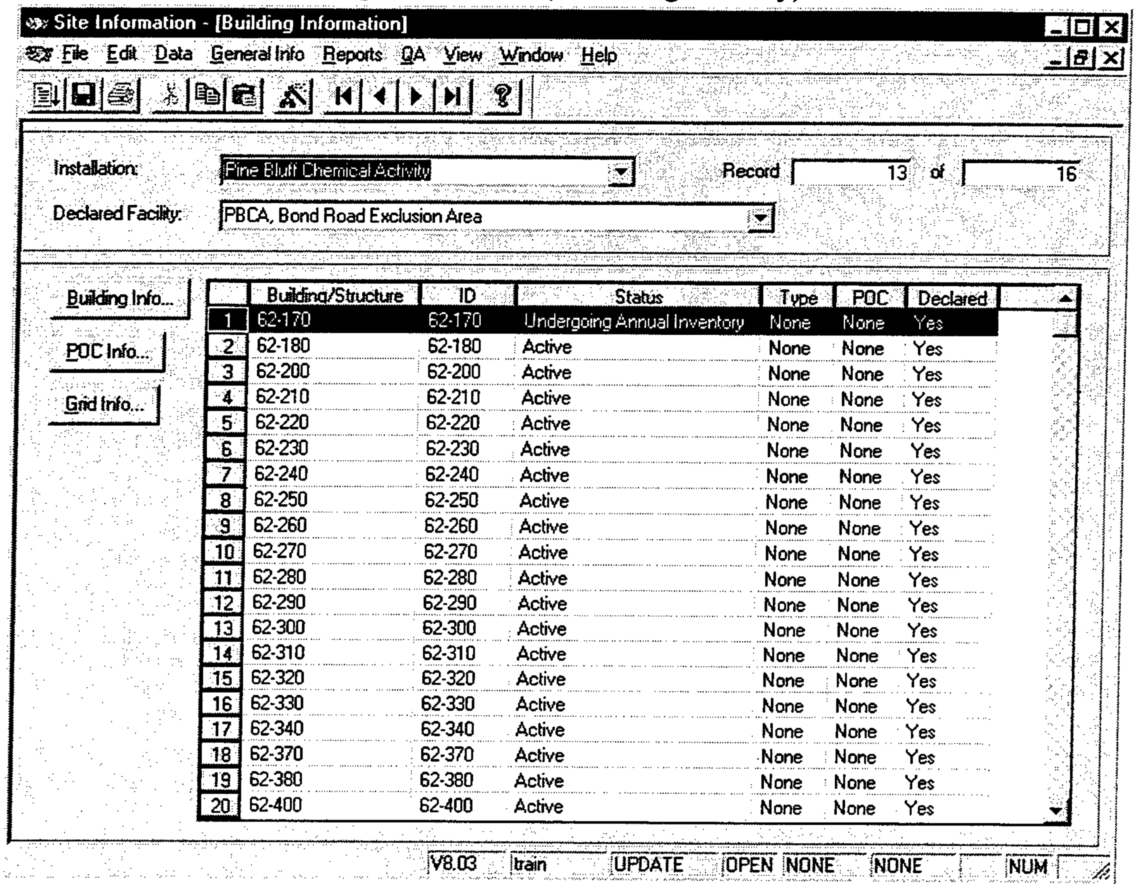
• General Data
    o Declared Chemical Information
    o Chemical Weapons Items
    o Site Information
        ▪ Installations and Plant Sites (Site Diagrams)
        ▪ Declared Facilities and Plants
        ▪ Building Information (Planographs)
• Data Access
    o Alerts
    o Data Download
    o Site Diagram Modifications
    o Reports Viewer
• Stock Records
    o Stock Records Maintenance
    o Materiel Release Information
    o Document Register
    o Annual Inventory
    o CW Destruction Reporting
• CWPF History
• Schedule 1 Permitted Activities
• Administrative Tools/User Administration
• Common Tools
    o CAMIN Settings
    o Data Administration
    o Ad Hoc Query
• Notifications and Declarations
    o Notifications Generation and Coordination
    o Notifications Catalog
    o Declarations Generation and Coordination
    o Declarations Catalog
	• Calendar
	• Report Generator
	• Notification Archive
	• Site Diagrams
	• Process Flow Diagrams
	• Newsletters
	• CCB Info
	• DMUG Info
	• Software Updates
	• Training Information
	• Policy Information
	• Documentation
	• Help
	• Administration
	• Links

Site Information > Installations and Plant Sites



The screen shown here displays the types of data CAMIN stores for an installation. CAMIN also has a screen for each facility that resides within an installation or plant site. CAMIN workstation users, with permission, can change the information. These data are used by both treaty and accountability applications in CAMIN.

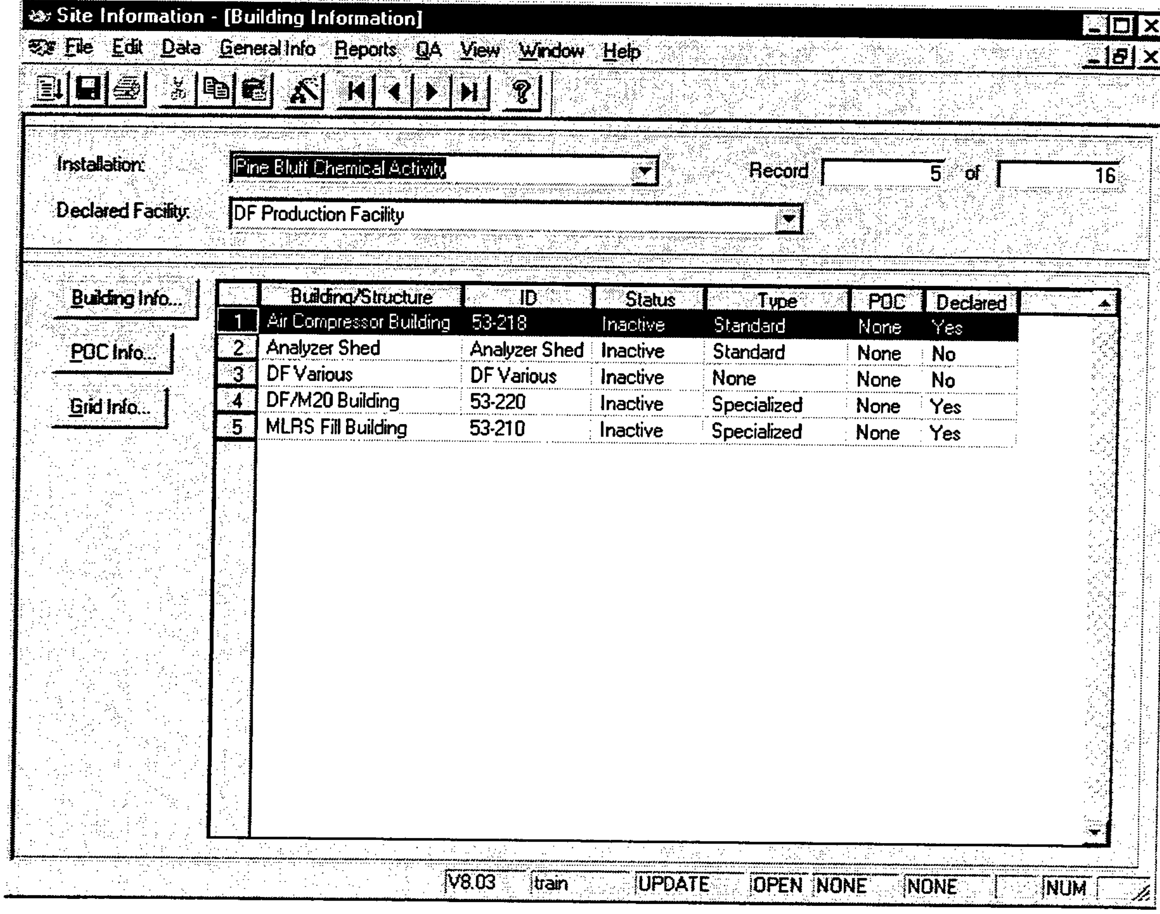
Site Information > Building Information (for Storage facility)



	Building/Structure	ID	Status	Type	POC	Declared
1	62-170	62-170	Undergoing Annual Inventory	None	None	Yes
2	62-180	62-180	Active	None	None	Yes
3	62-200	62-200	Active	None	None	Yes
4	62-210	62-210	Active	None	None	Yes
5	62-220	62-220	Active	None	None	Yes
6	62-230	62-230	Active	None	None	Yes
7	62-240	62-240	Active	None	None	Yes
8	62-250	62-250	Active	None	None	Yes
9	62-260	62-260	Active	None	None	Yes
10	62-270	62-270	Active	None	None	Yes
11	62-280	62-280	Active	None	None	Yes
12	62-290	62-290	Active	None	None	Yes
13	62-300	62-300	Active	None	None	Yes
14	62-310	62-310	Active	None	None	Yes
15	62-320	62-320	Active	None	None	Yes
16	62-330	62-330	Active	None	None	Yes
17	62-340	62-340	Active	None	None	Yes
18	62-370	62-370	Active	None	None	Yes
19	62-380	62-380	Active	None	None	Yes
20	62-400	62-400	Active	None	None	Yes

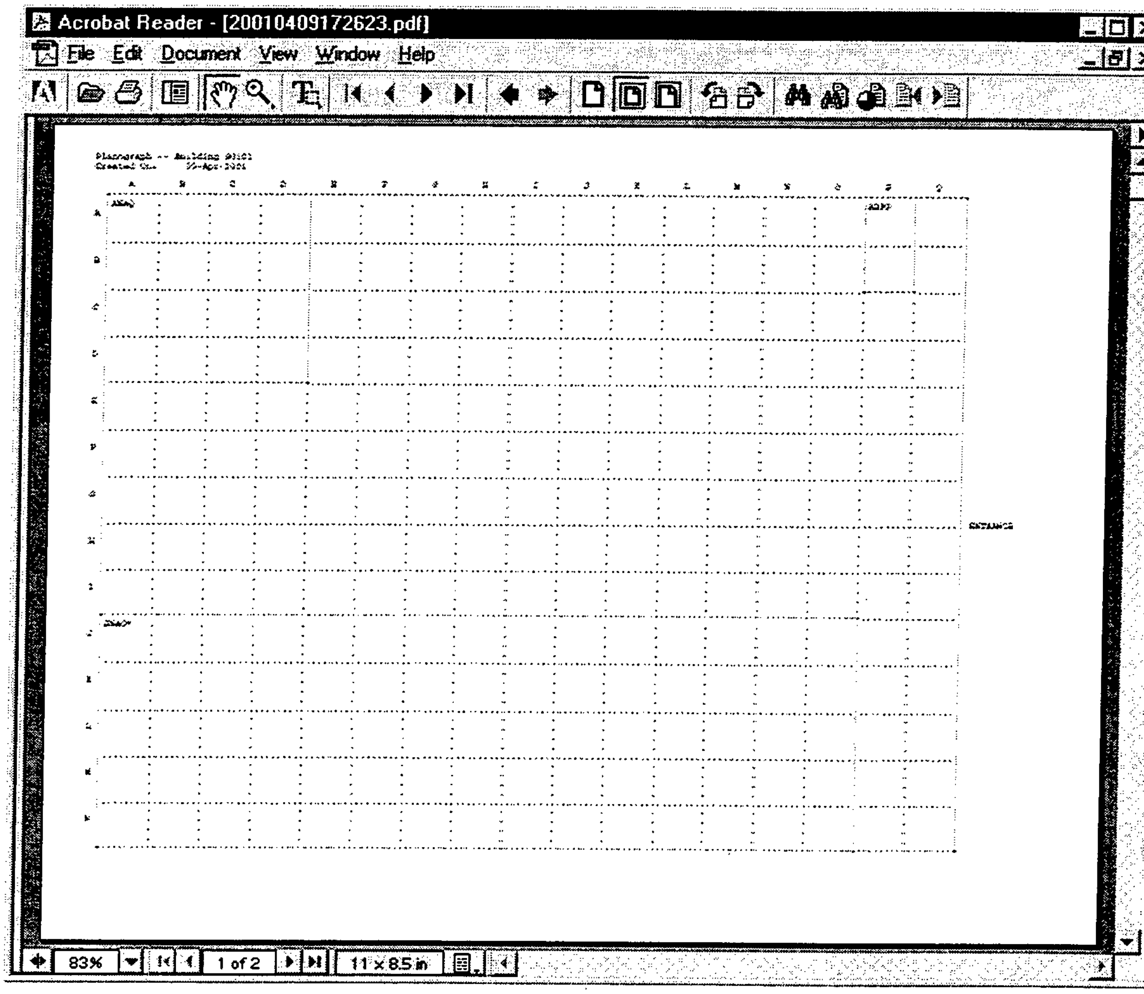
This screen shows an example of a building list in CAMIN for a storage facility. Each building may have unique grid layout that users would establish within this application. The first building on the list is currently undergoing annual inventory. The Annual Inventory application in CAMIN allows scheduling, printing out inventory worksheets, entering the completed inventory, and notifying the accountable officer of completion.

Site Information > Building Information (for CWPF facility)



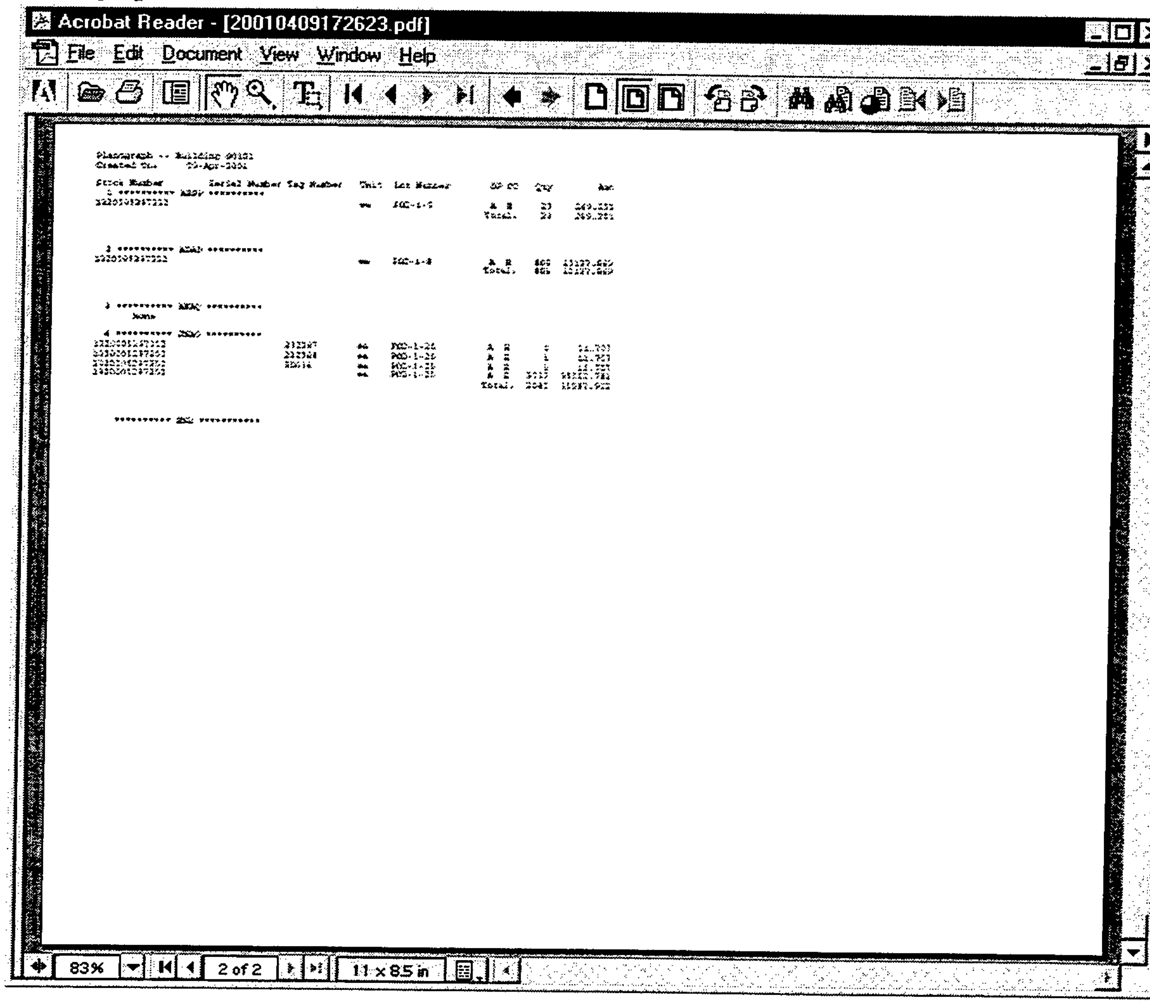
This screen shows a listing of buildings that would be associated with a former CW Production Facility (CWPF). The same application is used as for the last screen, but for a different purpose. Through reuse, CAMIN has saved development costs and avoided duplicate maintenance costs.

Planograph



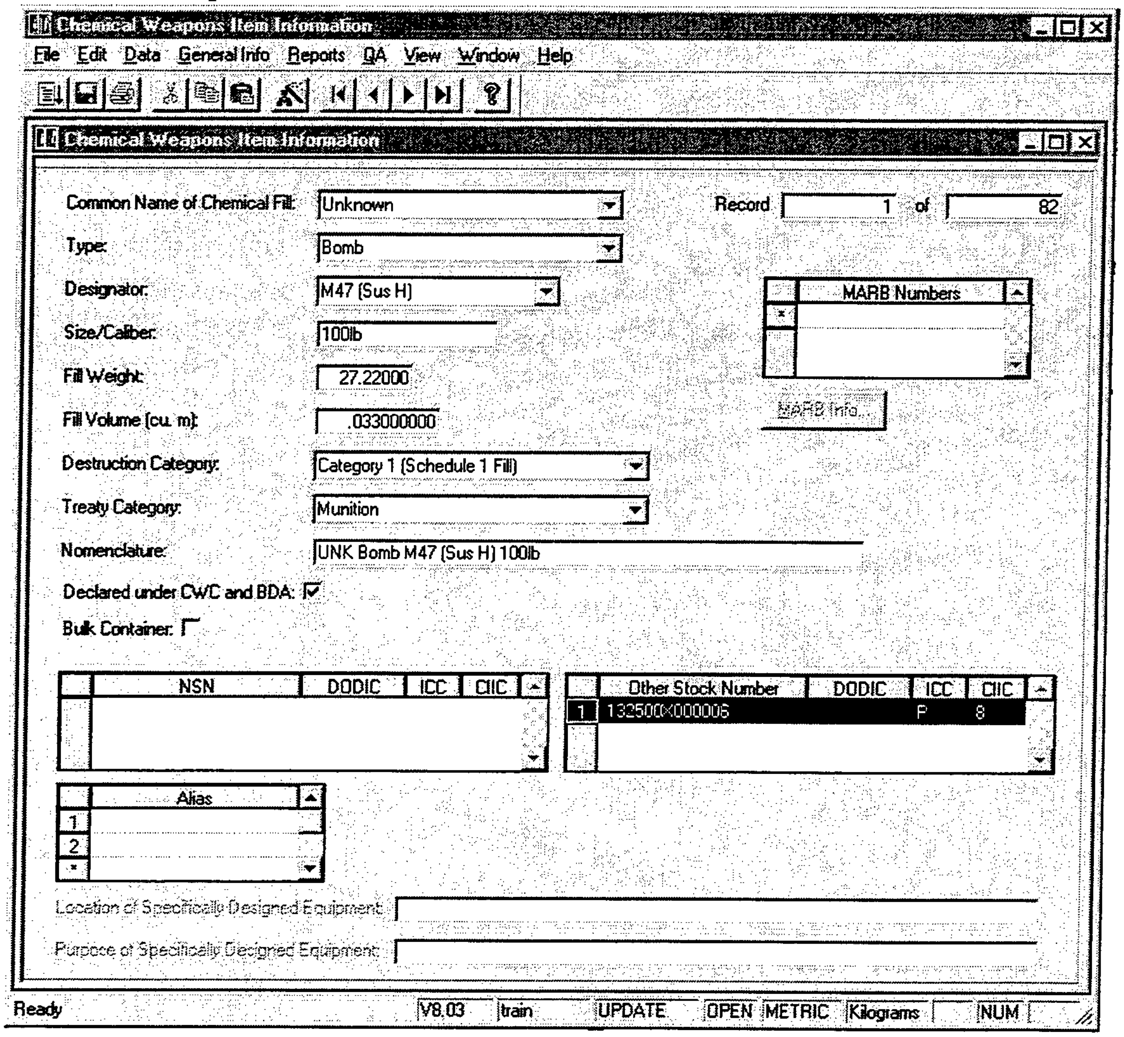
The Planograph is a map of a storage structure, showing grids where stock is stored. Each grid shown on the screen is listed on the next page, with the contents of that grid. Users enter the data used in creating the Planograph through the Stock Records Maintenance application.

Planograph Contents



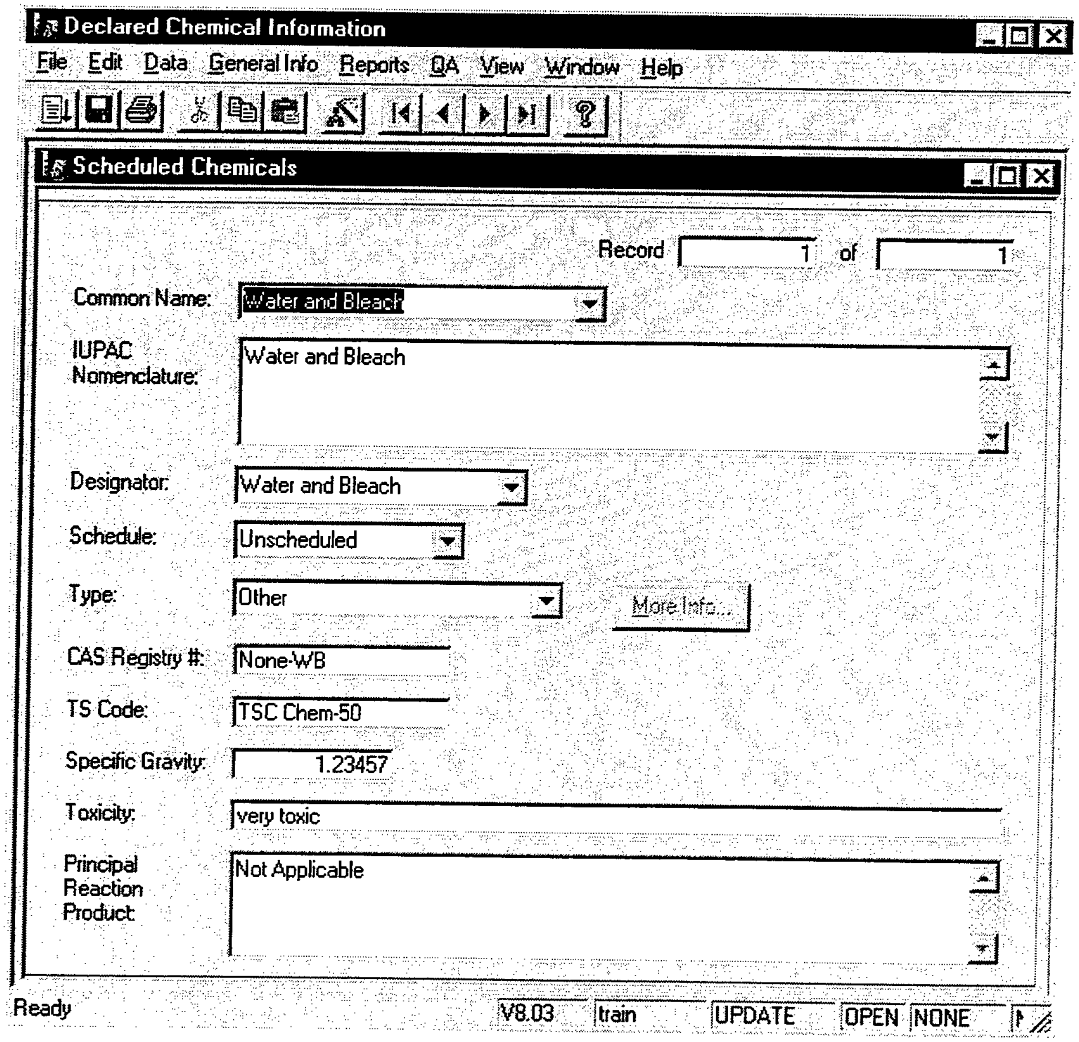
This screen represents the second page of a Planograph. This listing shows the contents of the structure by grid location. The Planograph is beneficial in annual inventories, maintenance activities, emergency response, and in treaty inspections.

Chemical Weapons Item Information



This application provides a dictionary of all CW items in the CAMIN system. The application creates a structured format for all nomenclatures, in accordance with the Chemical Weapons Convention. The application also creates a cross reference between nomenclatures and National Stock Numbers, to conform to the Army cataloging system. The nomenclature consists of four elements: 1) the name of the chemical fill, 2) the type of item, 3) the military designator, and 4) the size or caliber of the item. "None" or "unknown" are acceptable for almost every field.

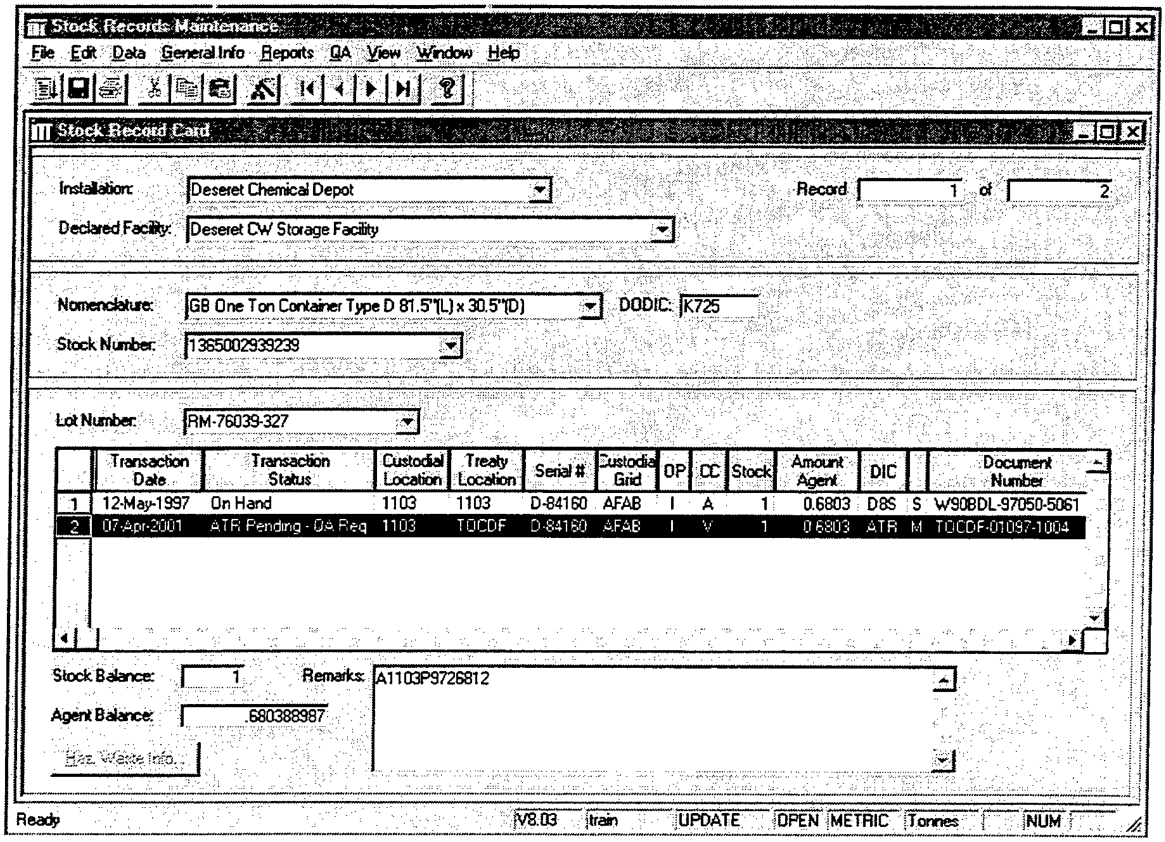
Declared Chemical Information



Each chemical fill in CAMIN is defined in this application. The chemical must be defined before a CW Item can contain that fill.

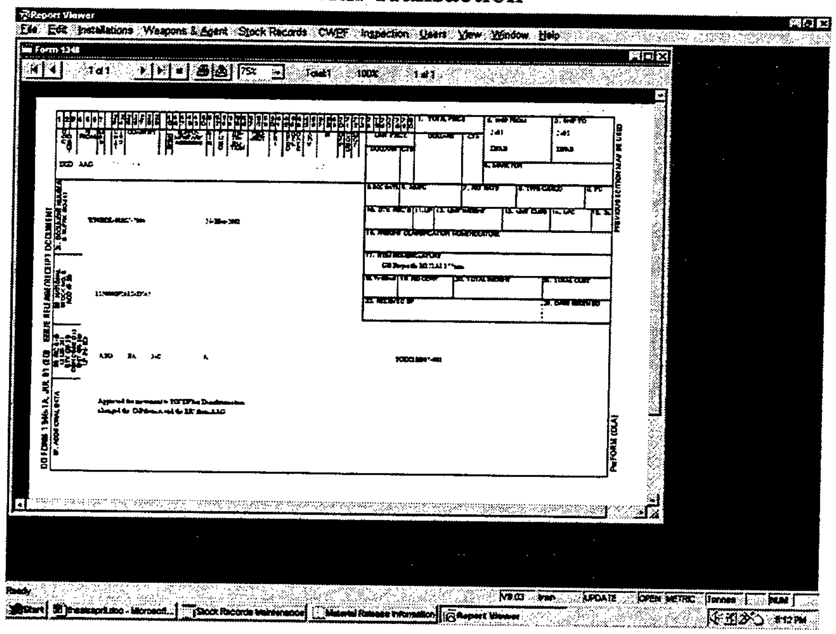
Both the CW Items and the Declared Chemicals Applications perform as dictionaries for CAMIN. Any change to these screens may affect multiple items located at multiple sites.

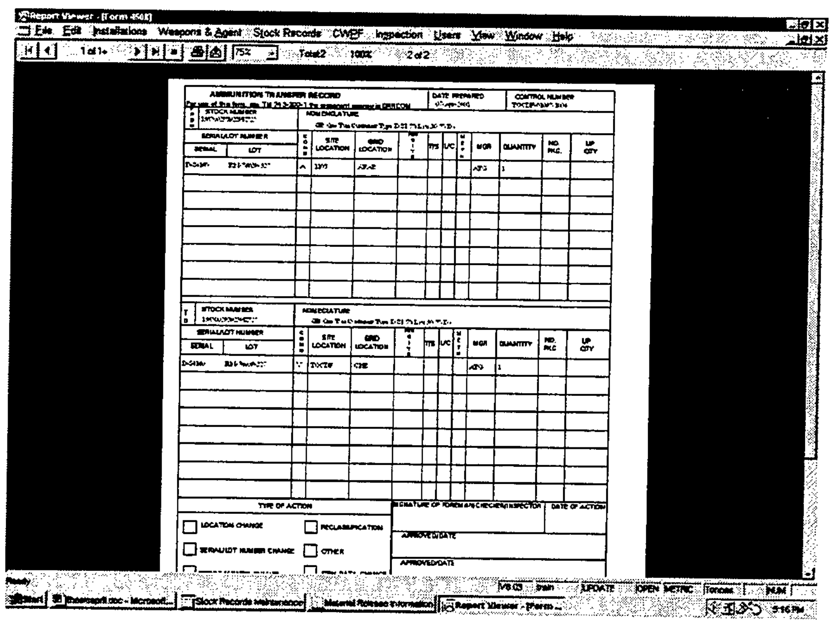
Stock Record Card for Chemical Items



This screen displays a single lot of an item, stored at a single facility. From this screen, the user with appropriate permissions at the facility can change characteristics of items or move items to another grid, building, facility, or installation.

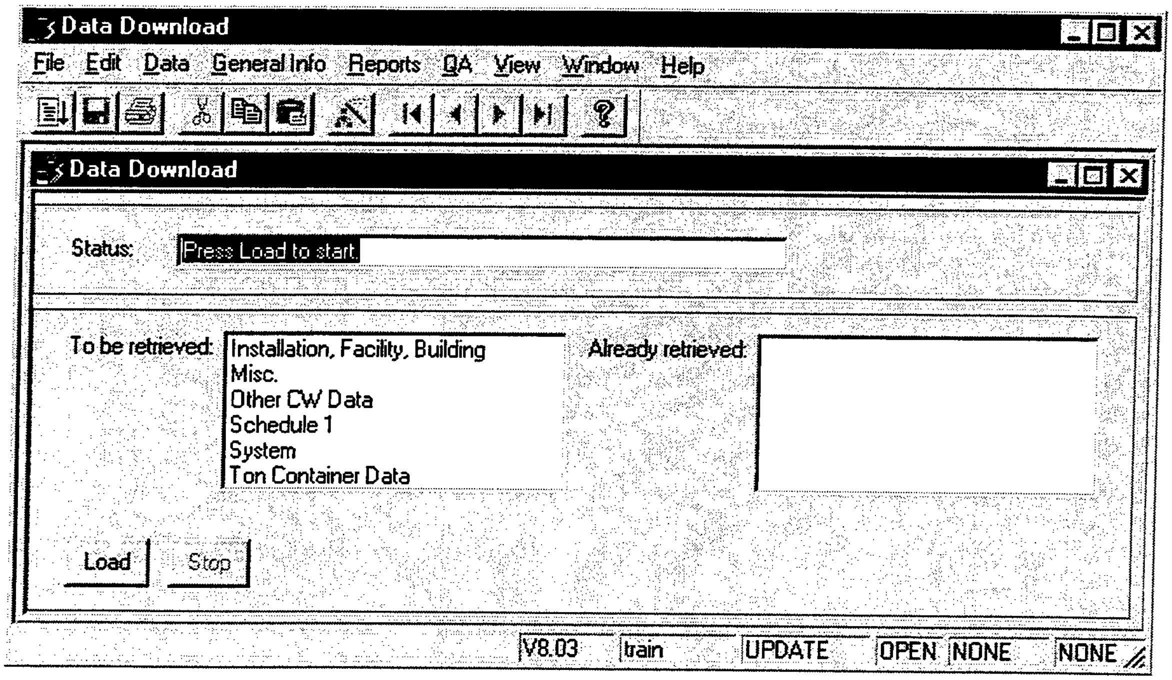
Document Associated with Transaction





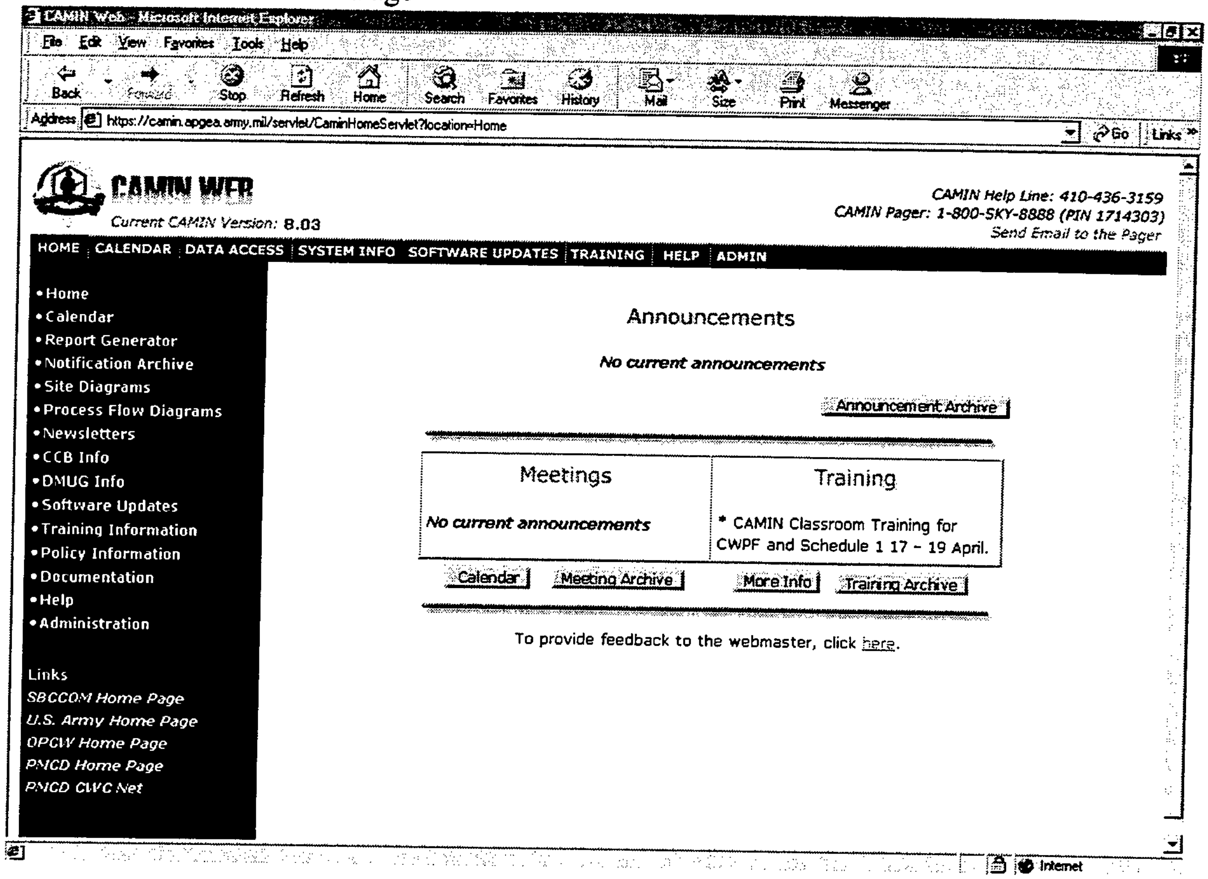
The CAMIN creates documents that are required by Army regulation for management of wholesale Army property. Regulations require these documents for changes to status or shipments.

Data Download



This application was not an original system requirement. It was part of a project to compensate for slow network connections at the Johnston Island facility. The Data Download application populates the lookup tables that reside on CAMIN workstations. Lookup tables contain data from the central server that changes infrequently. The CAMIN software uses the lookup tables to populate screens without receiving all data from the central server.

CAMIN Web Site Home Page



The CAMIN Web Site provides access to commonly needed data from the CAMIN server. The data presented by this web site is from the same source as the client system. The web site users can also get programmatic information, training, help, and calendar information.

Ultimately, this web site will support an increasing portion of the CAMIN client (workstation) capability. In this way, the PM can reduce the dependence on workstations and increase system access.

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